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Vol. 32 • Issue 7

Introducing the

Feature-for-Feature There is

PREMIUM MEADE® LXD75 OPTICS

Diffraction-Limited Optics Meade's Schmidt-Newtonian optics yield pinpoint stellar images over an extremely wide field-of-view with only half the coma of standard Newtonians of the same focal ratio.

Optical Tube Construction Schmidt-Newtonian and Schmidt-Cassegrain optics are mounted in precision-machined aluminum cells, which are then mounted in sturdy steel tubes and baked with high-grade textured enamel paint. The optical tube assembly is closed, reducing air currents inside the tube. This prevents distortion of an otherwise sharp image. Plus, a closed tube significantly helps keep the optics clean.

Corrector Lens Fully corrects for spherical aberration and provides pinpoint star images. Water white glass is used in all Schmidt-Newtonian and Schmidt-Cassegrain corrector lenses to maximize light transmission. The use of water white glass results in an increase of light transmission in excess of 10%, as compared to competitive telescopes using soda lime glass.

Individually Figured Optics Schmidt-Newtonian and Schmidt-Cassegrain corrector lenses and mirrors are individually figured to create a superior optical system which is renowned for its exquisite smoothness and performance.

Pyrex® Primary Mirror Premium-grade Pyrex mirrors are used in all Schmidt-Newtonian and Schmidt-Cassegrain optical systems, providing exceptional thermal stability versus competing models using standard plate glass.

Fast F/Ratios Meade's Schmidt-Newtonians have extremely fast, well corrected F/Ratios for short photographic exposure times and wide fields-of-view.

*Excludes Schmidt-Cassegrain. **SC-8 AT requires optional accessory

2" Focuser Aluminum rack and pinion focuser allows the user to achieve a precise focus.*

Eyepiece Holder Accepts both 1.25" & 2" eyepieces. Allows use of all common telescope accessories and cameras.**

8 x 50 Achromatic Viewfinder Easily locate and center deep sky objects (N-6EC model includes 6 x 30 viewfinder).

Made in the U.S.A. and Performance Tested All Meade Schmidt-Newtonian and Schmidt-Cassegrain optics are manufactured at Meade's state-of-the-art facility in Irvine, California—then performance tested on an Interferometer.

MEADE AUTOSTAR®

The AutoStar controller helps you quickly find, and *GoTo* over 30,000 objects in the night sky. View planets, stars, galaxies, nebulae, and comets…all at the push of a button. AutoStar is pre-programmed with several guided tours, including the popular *Tonight's Best*. Input date, time and location—then let AutoStar take you on a guided tour of the best objects that particular night. The AutoStar controller can be updated. Log on to Meade.com to download software upgrades, guided tours, and timely objects like comets—free. Keep your AutoStar up-to-date and your telescope will grow with you for years to come.

Optical Design	Newtonian	Schmidt-Newtonian					Schmidt Cassegrain	Achromatic Refractor		
Model	N-6 EC	SN-6 EC	SN-6 AT	SN-8 EC	SN-8 AT	SN-10 AT	SC-8 AT	AR-5 EC	AR-5 AT	AR-6 AT
Aperture	6" (152mm)	6" (152mm)	6" (152mm)	8" (203mm)	8" (203mm)	10" (254mm)	8" (203mm)	5" (127mm)	5" (127mm)	6" (152mm)
Focal Ratio	f/5	f/5	f/5	f/4	f/4	f/4	f/10	f/9	f/9	f/8
Focal Length	762mm	762mm	762mm	812mm	812mm	1016mm	2000mm	1143mm	1143mm	1219mm
Corrector Lens	N/A	Water White	Water White	Water White	Water White	Water White	Water White	N/A	N/A	N/A
Primary Mirror	Plate Glass	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®	N/A	N/A	N/A
Viewfinder	6 x 30	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50
Hand Controller	Electronic	Electronic	AutoStar #497	Electronic	AutoStar #497	AutoStar #497	AutoStar #497	Electronic	AutoStar #497	AutoStar #497
Price	$469	$639	$799	$799	$949	$1,099	$1,299	$679	$799	$999
Shipping	$75	$75	$75	$85	$85	$95	$85	$85	$85	$95
UHTC	N/A	$85	$85	$125	$125	$150	$175	N/A	N/A	N/A
Autostar Suite/LPI	$149	$149	Included Free	$149	Included Free	Included Free	Included Free	$149	Included Free	Included Free

LXD75™

No Comparison

ACHROMATIC REFRACTOR

SCHMIDT-NEWTONIAN

STABLE MEADE LXD75 GERMAN EQUATORIAL MOUNT

Sturdy Mount with Heavy-Duty Castings Designed by Meade's engineers and manufactured for high-performance observing and astrophotography.

Shaft & Bearing System The sturdy German Equatorial Mount is accurate and precise. The RA and Dec axes move effortlessly on four high-precision stainless steel ball bearings.

High-Precision Worm Gears Located on both axes for smooth tracking and slewing.

High-Precision Pointing (HPP) For even more precise pointing use the HPP function. HPP puts objects in the center of the field-of-view which allows you to confirm deep sky objects at the faintest limits of the telescope's capability.

Periodic Error Correction Corrects periodic errors on the RA axis over the course of one or more training periods, thereby minimizing guiding corrections during long-exposure photography.

9-Speed Drive Controls From a rapid slew rate of 4.5˚/sec. to 1x sidereal—it's all controlled from the AutoStar controller.

3-Star Alignment Accurately aligns the telescope's optical and mechanical systems so that more than 30,000 objects precisely enter your eyepiece.

Heavy-Duty Tripod Variable-height field tripod with spreader bar brace provides the stability and vibration damping required for visual observation and astrophotography.

Illuminated Polar Alignment Viewfinder For quick, precise polar alignment.

Power Supply Powered by 8 D-size batteries. Can also be powered by optional car cigarette lighter or AC wall adapter.

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Astrophotography can be intimidaing, but AutoStar Suite™ Lunar Planetary Imager (LPI™) lets even novice stargazers capture and process stunning images of the Moon, Saturn, Jupiter...and more.
$149 Value!

NEWTONIAN

SN-8

SCHMIDT-CASSEGRAIN

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Patents 6,304,376 and 6,563,636
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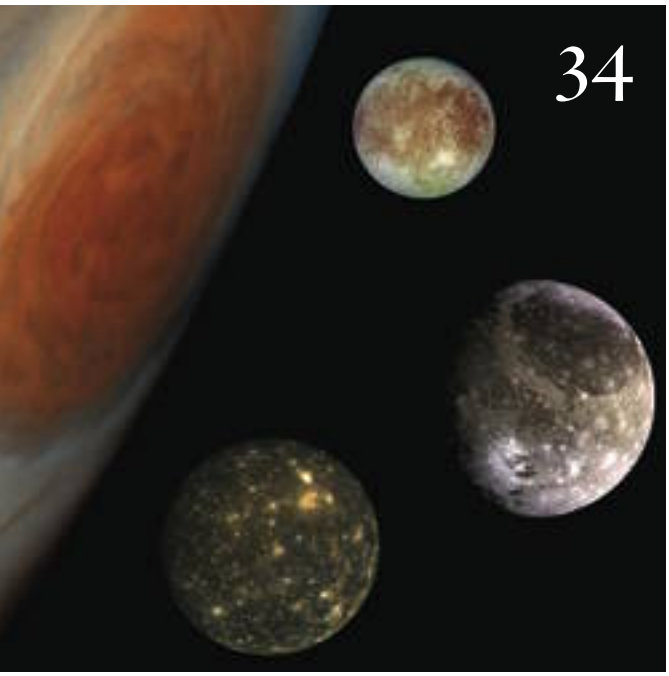
features



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COVER STORY
34 Jupiter's water worlds
The icy surfaces of Europa, Ganymede, and Callisto shroud oceans of liquid water, and one of these could harbor life within its depths. ROBERT PAPPALARDO

PLANETARY SCIENCE
42 How Earth got its Moon
The label "double planet," which often is applied to Earth and the Moon, carries some ironies. The pair that exists today is the result of a gigantic collision between a different, earlier "double planet" pair. PAUL D. SPUDIS

ASTRONOMICAL HISTORY
48 Did NASA fake the Moon landing?
A television show more than thirty years after the fact did not disprove that we landed six pairs of astronauts on the Moon. Most Americans believe that statement. Still, you may be interested in how we can prove it. RAY VILLARD

EXTRAGALACTIC ASTRONOMY
70 To the cosmic edge
Astronomers using the Hubble Space Telescope's Advanced Camera for Surveys have taken the deepest visible-light image ever, capturing thousands of galaxies out to the edge of the universe. FRANK SIETZEN, JR.

ASTRONOMICAL ART
78 Visions of space
Imagine having a ringside seat at the most magnificent cosmic events; space artists provide such a vantage point, allowing anyone to take vicarious journeys through the universe. ANDREW FAZEKAS

MOON OBSERVER'S NOTEBOOK
82 Touchdown at Tranquillity
This month, we celebrate the 35th landing of Apollo 11 on the Moon. So dust off your telescope and follow along as we take a detailed look at Tranquillity Base and its surroundings. ROBERT BURNHAM

EDUCATION
84 A visit to the planetarium
A universe of wonder under a dome near you, a planetarium brings much more than the night sky to visitors. Get a behind-the-screens look at planetaria and see where the field is headed. MICHAEL E. BAKICH

TELESCOPE REVIEW
88 Star power
The largest telescope manufacturer continues to improve one of its most popular products. How good can this telescope get? You're about to find out. STEVE EDBERG

DANIEL B. PHILLIPS

departments

6 This month in *Astronomy*
Is there life under the ice?

14 Letters

16 Bob Berman's strange universe
Cosmological chaos

17 Glenn Chaple's observing basics
Clubbin' astro-style

20 Interview
Ed Weiler, associate administrator for space science, NASA

24 News
- Seeing stars like sand
- Cassini/Huygens zero in on Saturn
- Sun's stellar neighbors run wild
- Microlensing finds a new planet
- Spiral canyons on Mars

54 The sky this month
Marvelous night for a moondance
MARTIN RATCLIFFE AND ALISTER LING

76 Ask Astro
Of time and space, the lowdown on space dust

96 New products
- ScopeTronix MaxView DSLR
- LPI's *Consolidated Lunar Atlas*
- SmartAstronomy's SmartCase
- Family ASTRO's *Moon Mission*

98 Book reviews
- *The Modern Moon: A Personal View*
- *Sky Vistas*
- *Strange Universe*

102 Coming events

103 Advertiser index

104 Resources

111 Reader gallery

ON THE COVER
Jupiter's banded clouds rotate slowly across the giant planet in the background as the dark, icy surface of its moon Europa receives an eerie, dim glow of sunlight. Underneath Europa's icy surface lies a briny ocean that may contain several times the amount of water in Earth's oceans combined. Another jovian moon, Io, lies between Europa and the planet. ARTWORK BY DON DIXON

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EARTH'S MOON: Watch a simulation of the collision that created our Moon.

THE GREAT MOON HOAX: Read about a fabricated lunar observation from 1835.

HUBBLE'S DEEP FIELD: Revisit the original image and its discoveries.

ASTRONOMICAL ART: Learn about the training, careers, and work of several artists.

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BY DAVID J. EICHER

Is there life under the ice?

With President Bush's space initiative

fresh in mind, Mars looms large as the place to look for life during the coming decades. First we'll go to the Moon, where we'll build bases, gather technologies, and then move on to the Red Planet. When the young kids of today are grown and holding down corporate jobs, building houses in the suburbs, we'll have something of an answer: either an astonishing fossil discovery or an underwhelming lack of finds — which will tell us something important about the precious nature of life on Earth.

But whether or not life exists or ever existed on Mars, there's another place in the solar system that could hold microbes — Jupiter's water worlds. Specifically, the place to look would be Europa, which has an icy shell that likely covers a vast ocean. Evidence for this comes largely from big cracks all over the moon's surface, which point to a briny ocean underneath a layer of ice. Europa's core is certainly iron, surrounded by a rocky mantle, but above that region may lie a considerable volume of liquid water more than twice that of all the oceans on Earth.

An experienced planetary scientist, Bob Pappalardo, guides you through the icy planets orbiting our largest planet in "Jupiter's water worlds" on page 34. Pappalardo, an assistant professor at the University of Colorado at Boulder, explains the amazing environment not only on Europa but also on its brethren, Ganymede and Callisto — bright jovian moons first spied by Galileo some 400 years ago. The spacecraft named for Galileo, Pappalardo reports, now has unveiled these distant worlds as distinct, icy, volatile places, each with a unique identity.

Closer to home, please welcome assistant editor Pamela Zerbinos to the *Astronomy* staff. Pam is a devotee of astronomy, astrophysics, and cosmology who has worked at the Fermi National Accelerator Laboratory and the American Physical Society before arriving at *Astronomy*. Pam is a native of North Carolina who has grown up in a military family and moved 18 times in her 24 years. She is now happy to have her feet on the ground in Milwaukee and her eyes aimed skyward. Her work background also includes writing for consumer and trade magazines, wire services, web sites, and newspapers.

ASSISTANT EDITOR PAM ZERBINOS joins *Astronomy*'s staff. *ASTRONOMY:* WILLIAM ZUBACK

We're sure you will enjoy Pam's writing and editing in many issues of the magazine to come.

Yours truly,

Dave Eicher
Editor

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LX90

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Worm gears of 4.9"-diameter on both telescope axes for smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging.

Die-cast-aluminum *double-tine* fork mount that rigidly supports the optical tube in all sky orientations.

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Rigid chromed-steel variable-height field tripod — *the same tripod provided with Meade LX200GPS models.*

Autostar™ Computer Controller: The LX90's *standard-equipment* Autostar controller permits an incredible array of telescope features:

- *Automatic GO TO capability* at 6.5°/sec on both axes, simultaneously, to 30,223 database objects, including:
- 13,235 deep-sky objects — the complete Messier, Caldwell, IC, and NGC catalogs; 16,888 stars; the 8 major planets; the Moon; 26 asteroids; 15 comets; 50 Earth satellites; plus 200 user-defined memory locations.
- *Automatic GO TO capability* to *any* object of known R.A. and Declination. Plus hundreds of special event menus, guided tours, utility functions, and telescope status options.
- *Nine selectable slew speeds:* 6.5°/sec, 3°/sec, and 1.5°/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- *Control of the telescope* through your personal computer. (Requires optional #505 Connector Cable Set.)
- *Fast alignment of the telescope* using any of three alignment functions, including the Meade-proprietary Easy Align.
- *Autostar is fully upgradeable over the Internet*: add the positions of new comets, update the positions of Earth satellites, even add new software.

With diffraction-limited optics in an Autostar computer-controlled telescope system, the Meade 8" LX90 includes capabilities not available on other brands of 8" Schmidt-Cassegrains costing hundreds of dollars more. Incorporating the optical system of the 8" LX200GPS, and with 5 arc-minute pointing precision in the GO TO mode, the LX90 is fully qualified for long-exposure CCD imaging and astrophotography as well as for other advanced photo-visual applications.

8" LX90
Schmidt-Cassegrain
$1695

SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally; see below); double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; Autostar Suite with imager; operating instructions. **$1695. Ultra-High Transmission Coatings (UHTC) group** increases image brightness by about 20%: add **$175.** Packing & shipping in the 48 states: $95.

The Meade 8" LX90 is manufactured under U.S. Patent Nos. 6,304,376 and 6,392,799; other patents pending in the U.S.A. and worldwide.

Included with LX90:
Meade Autostar Suite™ including LPI™ imager
A **$149** value!

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LX200GPS

10 REASONS WHY YOU SHOULD BUY A MEADE SCHMIDT-CASSEGRAIN:

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MEADE EXCLUSIVE
*Available as an option only at time of purchase.

2. Optical System – Meade utilizes water white glass as standard equipment in all 8", 10", 12", and 14" Schmidt-Cassegrain corrector lenses (UHTC and standard coatings) to maximize light transmission. The use of water white glass results in an increase of light transmission in excess of 10% as compared to telescopes using green soda lime glass.
MEADE EXCLUSIVE

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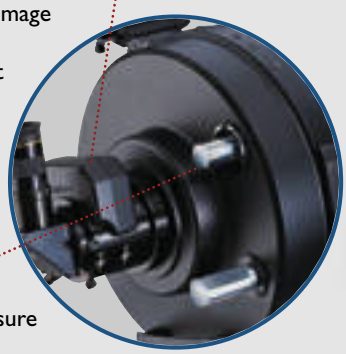
MEADE EXCLUSIVE



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MEADE EXCLUSIVE

14" LX200GPS-SMT

6. 16 Channel GPS Receiver with true-level sensor automatically inputs precise time, date, and geographical location to help quickly and precisely align and level the telescope.
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8. Smart Mount™ * constantly refines pointing accuracy each time an object is centered and updated. Compatible with equatorial and altazimuth mounts.
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*Can be purchased as an upgrade for older LX200GPS telescopes for only $99.

9. Autostar Update keeps your Autostar controller up-to-date with the latest software upgrades, guided tours, and timely objects like comets.
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10. Meade Autostar II handbox controller features "Hot Keys" for quick access to a 145,000 celestial object database.
MEADE EXCLUSIVE

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Manufactured under U.S. Patent Nos. 6,304,376, 6,392,799 and 6,563,636; other patents pending in the U.S.A. and worldwide.

* Hawaii and Alaska slightly higher–check with your Authorized Meade Dealer for exact pricing.

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10" LX200GPS-SMT	$2745	Free ($149 value)	$235	$145
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14" LX200GPS-SMT	$4995	Free ($149 value)	$350	$265
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* The Meade Ultra-High Transmission Coatings group must be ordered at the time of telescope purchase. The UHTC cannot be retrofitted.

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ULTRA HIGH TRANSMISSION COATINGS

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premium accessories

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- Features 2X digital zoom
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  - Red: Preserves your night vision.
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$299.00 (8.49)

Series 4000™ Super Plössls 52° field; multi-coated

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Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. **Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ 2x Apochromatic Barlow Lens

#140: 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images unmatched resolution, contrast and color correction. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: 2.5" long, works with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of longer focal-length Barlows. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces). **$42.95** (3.86)

2" Diagonal Mirrors with UHTC

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders. **#929** or **#930,** each: **$119.95** (6.85)

#911B

#908B

Series 4000 Nebular Filters—Premium multi-layer interference filters. Broadband ("B") filters block most forms of light pollution; narrowband ("N") filters are for heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)

#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)

#908N–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)

#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

#911X

#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)

#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes; 36mm dia. **149.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue — each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95**	(4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95**	(4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95**	(4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

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Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

HOW TO ORDER:

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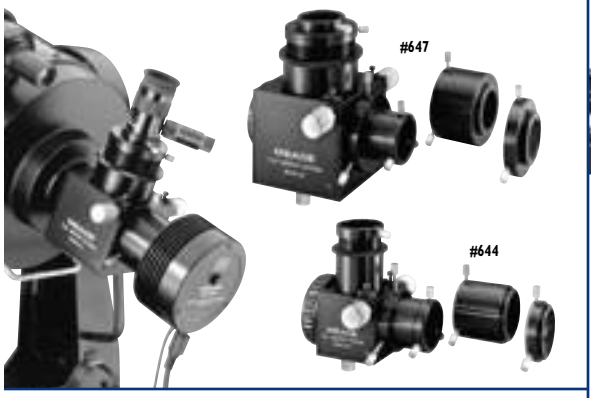
#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)



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T-Adapters for Schmidt-Cassegrains

Rigidly couples 35mm camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

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$39.95 (3.86)

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Professional-quality adapters for rigid coupling of telescope-to-35mm camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron Schmidt-Cassegrain. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your 35mm camera.

$39.95 (3.86)

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Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate handbox for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries.- **$249.95** (9.85)

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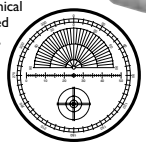

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Mistaken identity

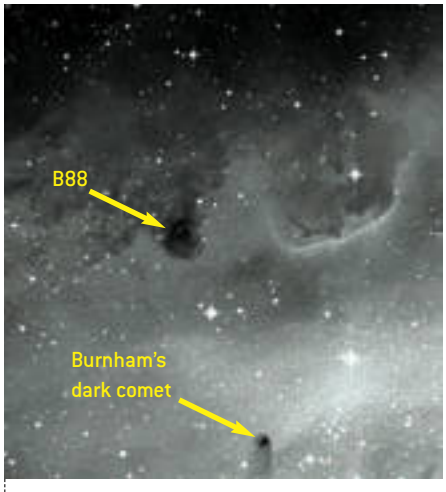
In the course of working on an article

on dark nebulae for the 2004 edition of the *Observer's Handbook*, we came across what appears to be an error in *Burnham's Celestial Handbook*. This error has led a generation of deep-sky observers to believe incorrectly that a smaller object 7' south and 2' west of the actual object cataloged by E. E. Barnard as B88 is, in fact, B88. While both nebulae are nice targets for amateur telescopes — indeed, perhaps Burnham's object is more "interesting" — we believe it is important that Barnard's object be known correctly to the amateur community.

On pages 1579 and 1581 of his *Celestial Handbook*, Burnham states that the "dark comet-shaped" object at the left edge of the photo on page 1581 is B88. Burnham refers to Barnard's 1919 *ApJ* paper (vol. 49, pp. 1–23), which gives the position of B88 in 1875 coordinates as R.A. 17h56m56s and Dec. –24°07'. He states the dimensions as 2.7' in north-south length and 0.7' in width. These coordinates precess to 2000 coordinates R.A. 18h04m35s, Dec. –24°07'.

A 15'-diameter POSS2/UKSTU image centered at these coordinates shows a dark nebula of the approximate stated size at this position; the object Burnham claimed to be B88 also is seen, but it is smaller and at the bottom of the image, about 7' south and 2' west of center.

Barnard's two-part posthumous work, *Atlas of Selected Regions of the Milky Way*, provides further evidence that the object at 2000 coordinates 18h04m35s, –24°07' is what Barnard designated as his object 88. This book was published in 1927, four years after Barnard's death, and others were partly responsible for some of the content. In the preface, however, written in 1927 by Edwin Frost, it is clearly stated that Barnard wrote the descriptions for the plates. The description for plate 30 in Part 1 says: "On the original negative, the details in Messier 8 are very clear and beautiful. Two of the remarkable, small, sharp, black spots are shown in the print, B88 in the north edge of the nebula and B89 southeast of the center." The (photographic) print in the book shows B88 in the location described; the "dark comet" also is visible, barely, but its position could not be described as "in the north edge."



BURNHAM'S DARK COMET is distinct from dark nebulae B88 in this POSS2/UKSTU image. STScI

Furthermore, a chart in Part 2 that serves as a finder for plate 30 marks B88. Apparently the charts in Part 2 were prepared by Barnard's assistant, Miss Calvert, under Barnard's supervision. The plate-30 chart, when compared with plate 30 itself, makes it clear that B88 is not Burnham's dark comet.

We cannot find any object in Lynds's 1962 *Catalogue of Dark Nebulae*, which is the other major listing of dark nebulae, that matches the position of Burnham's dark, comet-shaped object. So, it seems that Burnham's object is uncataloged. We suggest it simply become known as Burnham's Dark Comet and shed the incorrect designation B88 that many observers have come to know it by.

— PAUL GRAY, AUTHOR OF "DARK NEBULAE" IN THE 2004 RASC *OBSERVER'S HANDBOOK* AND **RAJIV GUPTA,** EDITOR, 2004 RASC *OBSERVER'S HANDBOOK*

A planet cornucopia

Following your advice (see "The sky this month," March 2004), I was able to see four naked-eye planets visible in the early March sky, and I expect to see another when Mercury appears later this month.

I would like to report that I also spotted one additional naked-eye planet. I spotted Jupiter, Saturn, Mars, and Venus, and then, I happened to glance down and, lo and behold, I spotted the third planet from the Sun right before my eyes. **— PEYTON ABBOTT,** PUEBLO, COLORADO

Why not go-to?

After several years of people arguing about the merits of "go-to" telescopes, one thing is clear: There is an old school, and a new school. The old school thinks the hardest way to discover things is the best way. After all, youngsters then will know what it was like back in the old days.

Why put obstacles in the path of people interested in the sky? Those who wish to learn star-hopping and similar techniques will; but those who want to learn about the sky shouldn't be told they have to walk up the mountain in order to see the valley; helicopters are available. Please, can we move past making fire with sticks?

— DAVE LUEPKE, CARROLLTON, TEXAS

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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RICHFIELD VIEWERS AND GUIDING EYEPIECE

BINOVIEWER

BY BOB BERMAN

Theory chaotic

Being a backyard astronomer is not confusing. The universe's beauty is obvious, as is the existence of its stars and planets. We gaze through our scopes at Jupiter and watch its ice-and-water moons whirling around like a staged snowball fight. Ours is a playground of glorious imagery, astonishing size, and mathematical motion.

Then there's cosmology. Dealing with the universe's birth, inventory, and evolution, it should theoretically round off our hobby and passion by putting our beloved targets — Saturn, Andromeda, and the rest — in perspective. It's where brilliant men and women stretch our minds by bringing us the latest cosmic concepts and discoveries. Isn't that fun?

Well, ten years ago it was fun. Now I'm not so sure. Back in the early 1990s, we seemed to have a handle on the whole thing. We had a Big Bang that was admittedly a weird event nobody could begin to explain. But like a bizarre sci-fi flick such as *Attack of the Killer Tomatoes*, once you accept the strange original premise, the rest more or less makes sense. You know the story: The cosmos starts out smaller than a pencil's eraser, having popped here from, in astrophysics jargon, "somewhere else." Then, by an unexplainable process dubbed inflation, it expanded faster than the speed of light. In less than a second, the whole inflation business was over and the universe started to coast. Scientists then said, "Okay, we'll handle it from here." They created good explanations for how three of the four forces were once unified (gravity never fit in) and how atoms, galaxies, and Rottweilers formed after that.

Through it all, one thing seemed certain: Gravity slowed expansion. The Holy Grail (circa 1993) was to pin down the strength of this "deceleration parameter" to see if the cosmos would ever re-collapse. It was a single-issue crusade, but headed in the wrong direction.

With a collective gasp, we learned, just as reality TV shows were becoming popular, something wacky happened before Earth was born: The cosmos started to expand *faster*. Its gears turned fast, slow, and fast again. Cosmology gurus figured 70 percent of the universe must be composed of an anti-gravity force called dark energy. This was fine except nobody had the slightest idea what that was. "It's the cosmological constant!" answered some, but they didn't know what *that* meant either. Others wondered, "Maybe it's a mysterious thing called quintessence, and the universe will expand at an accelerating tempo forever?"

Or maybe not. Some cosmologists believe dark energy may lose its oomph over time and could totally reverse its power, making the universe collapse.

Not so fast, say others. A new, trendy notion is that the cosmos could eventually produce a "Big Rip," causing everything — even atoms — to explode.

Pursuing yet another tack called string theory — which doesn't even work unless we give reality at least seven additional dimensions, none of which can be seen or tested — some maintain membranes existing in other dimensions occasionally touch one another, and *that's* what explosively creates things like our universe.

Suddenly, we're imbedded in a frothy quantum foam of unlimited possibilities. It's a free-for-all where each solemnly presented theory is soon changed or rebutted.

In one sense, it's very cool. Imagination rules! It's a unique period in cosmology's history. Throw the math this way, that way, tweak the equations, set fire to the physics building, nothing matters. It's *Alice in Wonderland* meets Stephen Hawking.

Unfortunately, cosmologists are starting to resemble naked emperors parading before the mass media. Hey, we love you, but you have *no* clue about the universe's true origin or fate, and little knowledge of its composition. Yet each pronouncement is delivered with pomp and flair. Maybe you need a serious "time out."

So how do *we* relate to all this? We should divide this magazine into two sections. The first deals with optics, gadgets, software, planets and nebulae, observations, beauty, and real science — like always. The other section has a disclaimer: "Warning: The following contains contemporary cosmology. Reading it can produce disorientation and confusion. Nobody knows what's going on and nothing you read here is likely to be true."

Then, we happily turn our scopes to the Moon and other favorites, knowing they'll be there tomorrow — no strings attached.

{ Warning: The following contains contemporary cosmology. Reading it can produce disorientation and confusion. Nobody knows what's going on.

Astro-socializing

We humans are, by nature, a social species. As amateur astronomers, however, we tend to become hermits. An e-mail from Richard Zappulla expressed the viewpoint that astronomy can be a lonely hobby. I agree. I've been outside on nights when the air was so still I could hear a dog barking miles away. All the houses in the neighborhood were dark, and, yes, it was a lonely feeling. But for me (and a lot of other amateur astronomers from what I hear), the solitude of the hobby is a big plus. A quiet evening alone under the stars is great therapy for anyone longing to escape the craziness of the everyday world.

As much as I relish those solitary times, there are occasions when, like Richard, I'd prefer a little company. So for you Lonely Hearts out there in Astronomyland, here are three ways to connect with your kindred cosmic souls:

1. Go to a star party

We're not talking balloons, presents, and ice cream and cake — it's not that kind of party. At a typical star party, an individual or group of amateur astronomers sets up telescopes for the viewing public. There may be an initial lecture, followed by the actual skygazing. Look for announcements in your local newspaper or on the bulletin boards of public buildings — especially libraries. Be alert, particularly when a special sky event, like a lunar eclipse or meteor shower, is in the offing. Contact the person or group holding the star party and offer to help by bringing your own telescope.

Can't find a local star party? Conduct your own! It could be as simple as a backyard gathering with a few neighbors or friends over, or (if you feel adventurous) a community event. In the latter case, you might consider limiting the number of attendees. Whatever option you choose, keep things lively by showing sky objects

STELLAFANE 2003 hosted telescope makers and more than one thousand amateur astronomers. PHIL HARRINGTON

— like the Moon, Saturn, Jupiter, or the Orion Nebula — to dazzle your guests.

2. Join a local astronomy club

Want to meet your fellow astronomy aficionados on a regular basis? Join a local astronomy club. Besides monthly meetings, where a guest speaker entertains and informs the club membership about a particular aspect of amateur astronomy, these organizations often sponsor regular observing nights (star parties) at a club site. A list of clubs in the United States and around the world can be found at *www.astroplace.com/amateurs/clubs.asp*.

If no club exists in your area, consider starting one of your own. After deciding on a place suitable for holding that all-important first meeting, post announcements in your local newspaper and in flyers located in strategic areas around town. The Astronomical League can provide information to anyone wishing to start an astronomy club. Check out their web site at *www.astroleague.org*.

3. Attend an astronomy convention

The ultimate social gala, astronomically speaking, is the astronomy convention. If you go to one of the large ones, like Stellafane in Vermont or Riverside in California, you'll find the same enthusiasm and cooperative spirit that makes star parties and astronomy clubs so special — on a much grander scale. By day, you'll rub shoulders with hundreds of astronomy enthusiasts like yourself. By night, you'll have your choice of dozens of telescopes to peek through.

A favorite smaller convention of mine has been the Astronomer's Conjunction, held in western Massachusetts. This intimate gathering draws a few dozen amateur astronomers to the Northfield Mountain Nature Center each September.

For a listing of upcoming astronomy conventions, check "Coming events" on page 102. Also, refer to *www.astronomy.com* or Phil Harrington's web site at *www.philharrington.net/swappe.htm*.

Regardless of the astro-social activity I pursue, the result is always the same: The next clear night when I'm back out alone under the stars, I have a renewed sense of enthusiasm for amateur astronomy. And I don't feel so lonely.

Next month: Chart a course for the Summer Triangle. (I know, I promised last time that we'd look at the Summer Triangle this month. But I had a bout of loneliness and decided to change the topic.) Until then, use the all-sky map on page 59 to locate and identify Vega, Deneb, and Altair and their parent constellations Lyra, Cygnus, and Aquila. Clear Skies.

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BY WILLIAM SCHOMAKER

Ed Weiler

Long before rocketing to his current post as NASA's associate administrator for space science, Ed Weiler's obsession with outer space took root in Chicago — amid the 1960s' Apollo-era enthusiasm. After fueling his interest in physics and astronomy at Northwestern University — and later at Princeton University — Weiler became

chief scientist for the fledgling Hubble Space Telescope in 1979. He paced nervously as Hubble's launch was delayed after the Challenger disaster and felt the sting of one of science's perfect failures when Hubble's mirror was found to be ground flawlessly in the wrong shape.

Now head of the most ambitious exploration and science program in the solar system, he has just one question for the armchair administrators who so adamantly oppose NASA's decision to discontinue service missions to Hubble: "Where was this attitude in 1990, when Hubble was broken and nobody would defend it?"

ED WEILER was the chief scientist of the young Hubble Space Telescope. Now, he agrees it's time to make some changes. NASA

With President Bush's renewed focus on human space exploration, will NASA's science programs lack funding?

No. The new mandate brings very good news for science. I've been at NASA for 25 years, and this is the first time we've really had a presidential directive that lays out a clear vision for the administration. We're going back to the Moon to practice living on another world so we can go to Mars and do some real science.

In particular, my budget for astronomy and space science increases about 41 percent under the president's proposed five-year plan.

Does discontinuing the servicing of Hubble diminish some of these gains?

I'm amazed by how many people get the idea from the media that we're going to shut down a fully-operating telescope tomorrow. That's not what the administrator has said. The administrator made a decision based on shuttle safety. And I mean no offense to my colleagues in astronomy, but unless an astronomer takes a two-or-three month crash course in shuttle engineering and risk analysis, it's a little disingenuous to get up and preach that you understand safety.

I'm fully confident that with a little ingenuity we can keep [Hubble] going at least until 2007, and maybe a little longer. Did you know we currently keep all the instruments running all the time, even when they're not in use? We have to start looking at some simple, commonsense alternatives to current practice, that's all.

Tell us about your early days as an amateur astronomer in Chicago.

Growing up, we had a 9-inch, black-and-white TV [at home] and three stations in Chicago. So forget about video games — we were outdoors and playing baseball all summer long. When I was about 12 years old, my Dad gave me some money and I sent off for a mail-order telescope. For $3, it had a 1-inch lens, cardboard tube, and a cheap eye lens. I looked at the Moon and Venus, and these were interesting enough for me to save up my money to get a 2.4-inch refractor on a little wooden tripod. And that got me more interested, to the point where I started grinding my own mirror. A year and about $100 later, I had built my own 6-inch f/8 reflector, bought an Erfle eyepiece, and started getting into wide-angle astronomy on star clusters and extended objects.

Some say the United States is mired in a math and science education crisis. If so, what can we do about it?

I've been saying that for ten years. It's scary because we're still graduating the same number of physicists and engineers and mathematicians, but the [total] number of U.S. graduates is going down each year. So where is that next generation of engineers, scientists, and mathematicians coming from? Are we content to let foreign countries provide all our technology in the future? That's not good for our [country's] economy, and some would argue that's not good for our security either.

If NASA can generate interest in science and in math, then every dollar we're spending on this stuff is worth ten times that much in the end. Just thirty days into the recent Mars missions, our rovers generated six billion hits on the Internet, and 1.2 billion of those were from kids — that's a lot of hits.

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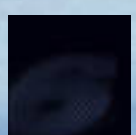

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No Purchase Necessary. The official start date for the Astronomy Summer Sweepstakes is April 23, 2004. Official entry forms are bound in the June, July and August 2004 issues of Astronomy. The Astronomy Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependants and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, zip and telephone number on a postcard and sent it to: Astronomy Summer Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. Or enter online at www.astronomy.com by filling in the Online Entry form and hitting the SEND key. The Online Entry form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the Astronomy Summer Sweepstakes is August 6, 2004, and all entries must be transmitted or postmarked no later than that date.

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GAMMA-RAY BURSTS NO LONGER OCCUR FREQUENTLY in the nearby universe, according to a study of 1727 long-duration bursts. The massive stars whose collapse leads to bursts formed predominantly in the early universe.

news 07

Read all about it: seeing the black hole at the Milky Way's center, the universe's peak of star formation, methane on Mars, and Jupiter's impending climate change.

HUBBLE HERITAGE IMAGE

Seeing stars like sand

Stars appear like grains of sand on a beach — or dust on a tabletop — in this image of the spiral galaxy NGC 300. NASA's Hubble Space Telescope, seeing ten times better than ground-based telescopes, can spot stars as individual points of light, even though they're 6.5 million light-years away.

NGC 300, a spiral galaxy similar to the Milky Way, lies in the Sculptor Group, the nearest group of galaxies beyond our own Local Group. The Sculptor Group is the subject of the Araucaria Project, which is studying NGC 300 and other galaxies in hopes of better calibrating the scale used to measure distances between galaxies.

Astronomers measure distances with stellar standard candles such as Cepheid variables. These have easily determined periods and luminosities that yield distances. But astronomers don't know how environmental properties of host galaxies affect the standard candles they contain.

The Araucaria Project seeks to fill this knowledge gap for the most important stellar candles, including Cepheid variables, RR Lyrae stars, red clump giants, and blue supergiants. All of these might provide accurate distance determinations to nearby galaxies — once their environmental dependencies are known.

The team has been studying NGC 300 since 2001, mostly using ground-based telescopes. The HST images will provide accurate photometric data about blue supergiants and Cepheids. The images also will help astronomers check the Cepheids for companion stars, which would throw off the luminosity measurements and give an inaccurate distance calculation. — **PAMELA ZERBINOS**

THE PINPOINT STARS of NGC 300 in Sculptor are helping astronomers determine the distance to this and other galaxies. NASA/STScI

26 Cassini/Huygens zero in on Saturn

28 Sun's stellar neighbors run wild

30 Microlensing finds a new planet

32 Spiral canyons on Mars

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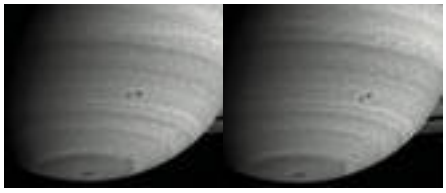
PLANETARY EXPLORATION

Cassini closes in



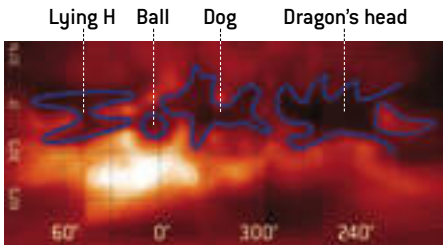
TWO STORMS SLOWLY MERGE in these Cassini images from March 2004, taken as the spacecraft drew near the planet. The storms lay in Saturn's mid-southern latitudes. NASA/JPL

As the Cassini spacecraft approached Saturn, its imager caught two small storms merging and photographed the two moons that shepherd the thin F ring.

Planetary scientists on the ground have mapped broad surface features on Titan using infrared wavelengths that penetrate the moon's smoggy atmosphere. In other findings, scientists predict that if Titan has liquid methane or ethane oceans, then the waves should rise seven times higher than those on Earth but travel a third as fast.

Last, X-ray observations made as Titan transited the Crab Nebula showed the moon's atmosphere extends 550 miles (880 km), higher than when Voyager 1 flew by in 1980. Saturn then was farther from the Sun and cooler. **— ROBERT BURNHAM**

SMALL MOONS Pandora (upper) and Prometheus (lower) herd Saturn's thin F ring with their gravity. Below, the ground-based Very Large Telescope imaged surface details on Titan using infrared light. NASA/JPL; ESO



Fixing a space probe en route

WHAT WILL GREET HUYGENS as it lands on the surface of Titan is still a mystery. But an inventive in-flight "fixit" solved a problem that would have silenced the probe. M. ROBERTSON-TESSI/R. LORENZ ARTWORK

Earth's biggest interplanetary mission, Cassini-Huygens, is approaching Saturn, and scientists and engineers have high hopes for discoveries on the scale of Galileo's jovian reconnaissance.

One reason for such hopes is the high level of insight and competence shown by the probe's operators. They have already diagnosed and fixed a fundamental design flaw in the communication system — all by remote control.

After spending half a year in preliminary orbits, Cassini will detach its European-built Huygens entry probe and send it toward Titan and its mysterious surface. The probe will relay data all the way down to the ground and, with luck, after landing as well, at least briefly.

But Huygens was almost doomed to fail. A subtle design flaw in the European-provided receiver on Cassini would have locked out much, if not all, telemetry from Huygens. Once the flaw had been detected, NASA mission planners found a solution.

The combination of Cassini's tremendous speed and the sharp deceleration of the probe created a large Doppler shift in the probe's signals. The frequency change was expected. But the compression of timing pulses would have kept the receiver from synchronizing the incoming data and resending it to Earth.

Three review panels and an exhaustive testing program failed to find the problem before launch in 1997. Yet the long cruise gave time for tests. One communications engineer grew suspicious and insisted that tests include a sequence of pulses simulating signals from the lander to the mother ship.

Once the problem was uncovered, the team reduced the Doppler shift so the timing pulses remain just within the receiver's range. This will be accomplished by deploying the probe not during the first approach but after Cassini has orbited Saturn for several months. Also, Cassini's altitude will be higher as it flies past Titan while the probe is entering the atmosphere. This rearrangement puts most of the probe's deceleration at right angles to the Huygens-Cassini line-of-sight, keeping the Doppler change acceptable.

The Huygens probe still faces enormous engineering challenges to survive at Titan. But thanks to some insightful worrying and an inventive fix, the deck isn't entirely stacked against it. **— JAMES OBERG**

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RITI Lunar Map Pro

RITI has unveiled Version 3 of its popular Lunar Map Pro, adding nearly 700 locations to its extensive database of lunar features and sites. Version 3 also features a 3D terrain viewer and a point-of-view manager that duplicates views from orbit as well as those from your own back-yard. Lunar Map Pro displays lunar maps based on enhanced versions of NASA's highest-resolution raster images, and it contains the most detailed and accurate lunar GIS vector-outlines map available. If your needs aren't quite as extensive, the Basic Edition offers a database of 1620 named and categorized features, including manned Apollo sites, to explore and locate.

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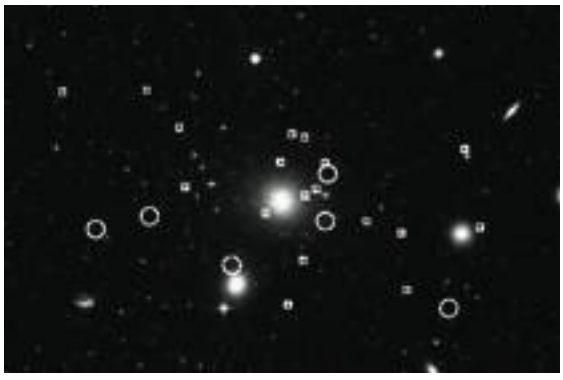
EXTRAGALACTIC ASTRONOMY

Mini-galaxies discovered



A NEW KIND OF MINI-GALAXY has been found in Fornax that may be the stripped remnants of dwarf galaxies. Small circles mark recent discoveries; the large circles are older ones. AAT/BRISTOL UNIV.

A new survey with the Anglo-Australian Telescope has revealed dozens of previously unsuspected miniature galaxies in the nearby Fornax galaxy cluster. They belong to a class of galaxies dubbed ultra-compact dwarfs (UCDs).

Researchers say UCDs outnumber conventional spiral and elliptical galaxies in the Fornax cluster's central region. The UCDs have been overlooked because they resemble nearby stars. (The study, presented April 1, 2004, at the Royal Astronomical Society's national meeting, also found UCDs in the Virgo cluster.)

UCDs were discovered in 2000, when Stephen Phillipps (Bristol University) and colleagues surveyed every moderately bright object visible in the direction of the Fornax cluster. Measuring the objects' redshifts showed that six objects resembling local stars in our galaxy were, in fact, in the Fornax cluster — about 60 million light-years away.

Follow-up observations with the Hubble Space Telescope and the European Southern Observatory's Very Large Telescope revealed that UCDs have masses similar to dwarf galaxies but are amazingly small, only about 120 light-years across. This means tens of millions of stars jostle in a volume that's tiny by galaxy standards.

The team proposes that UCDs are the nuclei of larger galaxies that have been stripped of their outer stars through collisions. Testing this idea, the team uncovered 46 additional UCDs in Fornax, where galactic collisions should have been prevalent due to crowding. — **P. Z.**

PLANETARY SCIENCE

Mars has methane

The Mars Express spacecraft has detected very small amounts — about 10 parts per billion — of methane in the martian atmosphere. Possible origins include volcanism, meteoritic debris — and biological activity.

Methane is removed from the atmosphere through reactions in a few hundred years. Its presence therefore implies a continuing source.

Scientists need to collect more data on the methane's distribution in the atmosphere. They are also looking for possible volcanic hotspots that might provide a source active right now or in recent times. — R. B.

VOLCANIC ERUPTIONS may be the source of martian methane. ESA/FU BERLIN

PLANETARY SCIENCE

Will Jupiter lose its spots?

Jupiter could lose most of its spots in the next decade, says Philip Marcus (University of California, Berkeley). Writing in *Nature* (April 22, 2004), he describes a mathematical model of the jovian atmosphere that explains the disappearance of two white ovals in 1997–2000 as part of a pattern of climate change.

During each cycle (which lasts about 70 years), spots form quickly, then turbulence slowly erodes them, Marcus says. This causes Jupiter's equator to warm slightly while its poles cool, triggering a new wave of spot formation.

"Watch for changes, especially around 35° south," says Marcus. — **R. B.**

JUPITER MAY LOSE most of its spots in the next 10 years. STScI

GALACTIC ASTRONOMY

Solar neighbors run wild

A 15-year survey of stars in our galactic neighborhood shows a lot more stellar mixing than expected.

"For the first time, we can study the Milky Way's history in three dimensions," says Brigitta Nordström (Niels Bohr Institute, Copenhagen), who led the study, which involved over 1,000 nights' observations. The survey showed that many stars near the Sun are transitory, passing by on the way to someplace else.

The Sun lies in the outer portion of one of the galaxy's arms, about 26,000 light-years from its center. An animation tracing solar movements backward 250 million years (about one galactic orbit) shows the Sun's present-day neighbors once scattered throughout a quarter of the galaxy.

"Milky Way models have long assumed that the galactic disk near the Sun evolved quietly and essentially in isolation," says Nordström, "but its life has been rather turbulent." — **P. Z.**

THE SUN'S neighbors, driven by galactic turbulence, are mostly just passing through. ESO ARTWORK

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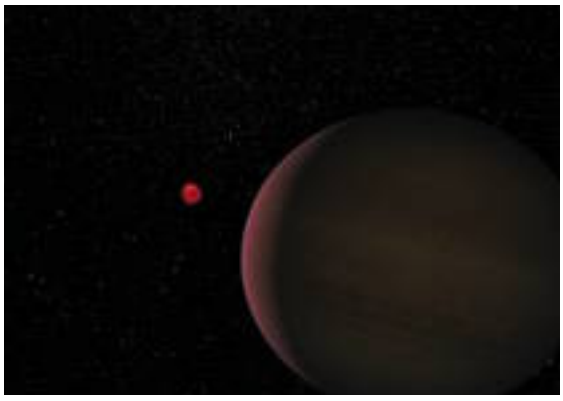
Solar Image by Jack Newton. www.jacknewton.com

A NEWLY DISCOVERED METEOR SHOWER appears associated with an Earth-approaching asteroid, 2001 YB5. The shower peaks around January 7 and produces about 13 meteors per hour. Its radiant lies at R.A. 8.1h, Dec. +11.5°.

STELLAR ASTRONOMY

Microlensing finds a world

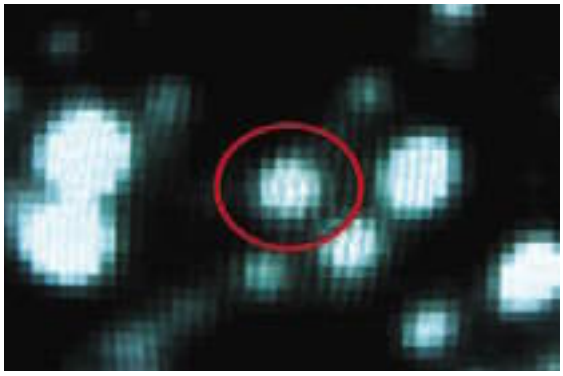


A GAS-GIANT PLANET orbits a red dwarf star lying 17,000 light-years from Earth. It is the first planet found using the "microlensing" technique and the farthest planet known. NASA/JPL-CALTECH

A transitory and irregular brightening of a distant star has told astronomers, through an effect called gravitational microlensing, that a closer star has a planet. The planet orbits a red dwarf star in Sagittarius; the star and planet drifted in front of another star lying 24,000 light-years away, and their combined gravity briefly magnified the more-remote star's light.

But because the nearer star and its planet both exerted a gravitational effect, the brightness change was not a simple pulse. Careful analysis revealed the existence of the planet, showing that it has about 1.5 times the mass of Jupiter and orbits at 3 times the Earth-Sun distance from its star.

Microlensing can help astronomers detect low-mass planets, but it requires them to keep thousands or millions of stars under watch at once. — **R. B**



A BLIP OF LIGHT from a distant star helped astronomers discover an intervening star-and-planet system. The technique will soon be sensitive enough to find Earth-mass planets. SDSS/R. LUPTON

STELLAR ASTROPHYSICS

Into McNeil's Nebula

Amateur astronomer Jay McNeil noticed a new, bright spot near M78 in Orion in January 2004. Studied by professional telescopes, McNeil's Nebula turns out to be a newly formed star with very strong stellar winds.

"The nebula is allowing us to add another important piece to the puzzle of the long birth of a star," says Bo Reipurth (University of Hawaii), who published the first paper on the nebula with colleague Colin Aspen.

"We know so little about these kinds of eruptions," says Aspen. — JEREMY McGOVERN

McNEIL'S NEBULA, enshrouding a new star in Orion, was found by an amateur. GEMINI OBS.

GALACTIC ASTRONOMY

Supermassive black hole imaged in radio

The supermassive black hole at the center of the Milky Way has been imaged by radio astronomers led by Geoffrey C. Bower (University of California, Berkeley).

They used the Very Long Baseline Array to view the galactic center at 1 millimeter wavelength and published the work in *Science Express* (April 1, 2004).

The images show the event horizon of the black hole silhouetted as radiation from the inner galaxy passes around it — or falls in.

The black hole has a diameter roughly 100 times the Moon's distance and weighs about 3 million solar masses. — **R. B.**

A DARK SILHOUETTE marks the edge of the black hole at the Milky Way's heart. NRAO

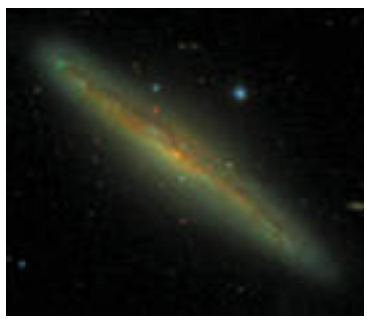
STELLAR ASTRONOMY

Star-formation rate in decline

The universe is 13.7 billion years old but reached a peak of star-producing power 5 billion years ago, says a team of astronomers led by Alan Heavens (University of Pennsylvania). The team sifted data from the Sloan Digital Sky Survey for 96,545 nearby galaxies to trace the history of star formation. Their results appear in the April 8, 2004, issue of *Nature*.

By the time our Sun was born some 4.6 billion years ago, the team writes, almost half the stellar mass in the universe had been created already.

Star formation has slowed drastically since then — and because old stars are dying faster than new ones are being born, the universe is doomed to become a much dimmer place in the future. — **P. Z.**



A SURVEY OF NEARBY GALAXIES lets astronomers trace the star-making history of the universe. SDSS/R. LUPTON

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DSLR II shown on a Canon 10D*

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STUDIES OF DISTANT QUASARS SHOW an important physical quantity – the fine-structure constant – has not altered as the universe has evolved. This contradicts an older, less precise study suggesting the opposite.

Old craters re-emerge

EXHUMING BURIED CRATERS reveals details of a long-vanished landscape in this Mars Odyssey THEMIS image of Terra Meridiani near 5° north and 357° east. NASA/JPL/ASU/IMAGE 20040317A

PLANETARY SCIENCE

Down in the valley

Ius Chasma forms part of Mars's Valles Marineris. This image by the High Resolution Stereo Camera on Mars Express shows the channels of Louros Valles feeding into Ius. The dark material in Ius may be deposits left by wind or water. — R. B.

SEEPING GROUNDWATER cut channels that flow into Ius Chasma (top). ESA/DLR/FU BERLIN

MARS PHOTOJOURNAL

A MARTIAN VERSION of Arizona's Meteor Crater lies in Cydonia, although it's a little smaller than the terrestrial example. Erosion has taken rock away from around the crater while also removing later-deposited mantling material. The image, sunlit from the lower left, is 1.9 miles (3 km) across. NASA/JPL/MSSS/IMAGE R13–02121

PLANETARY SCIENCE

Why do Mars's polar canyons spiral?

Spiral canyons in the martian polar caps (see the northern cap at right) present a long-standing puzzle. New work by Jon D. Pelletier (University of Arizona) shows that they formed fairly simply, however.

"Cracks and crevasses in the ice with Sun-facing walls give off water vapor and widen," he says. "Also, heat diffuses into the ice, which carries warmth to areas that don't face the Sun."

Using equations that describe some chemical reactions and the growth of slime molds, Pelletier found that spiral canyons formed and grew in his model ice caps — and their shape closely matched the real thing.

Pelletier found that water vapor released by sunlight didn't go far — it hung like a fog in the crevasses, with a lot of it refreezing on the shadowed walls.

SPIRAL CANYONS in the martian polar caps have puzzled scientists since the 1970s. NASA/GSFC/MOLA TEAM

"If Mars were much warmer," he says, "the caps would just disappear. And if it were much colder, the canyons couldn't form." — **R. B.**

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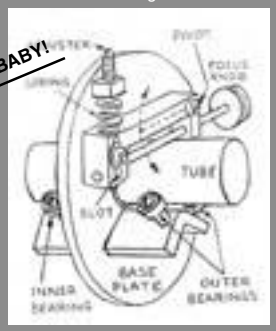
One of J Wall's original sketches



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(The name came from his club, Crayford Manor House Astronomical Society.)

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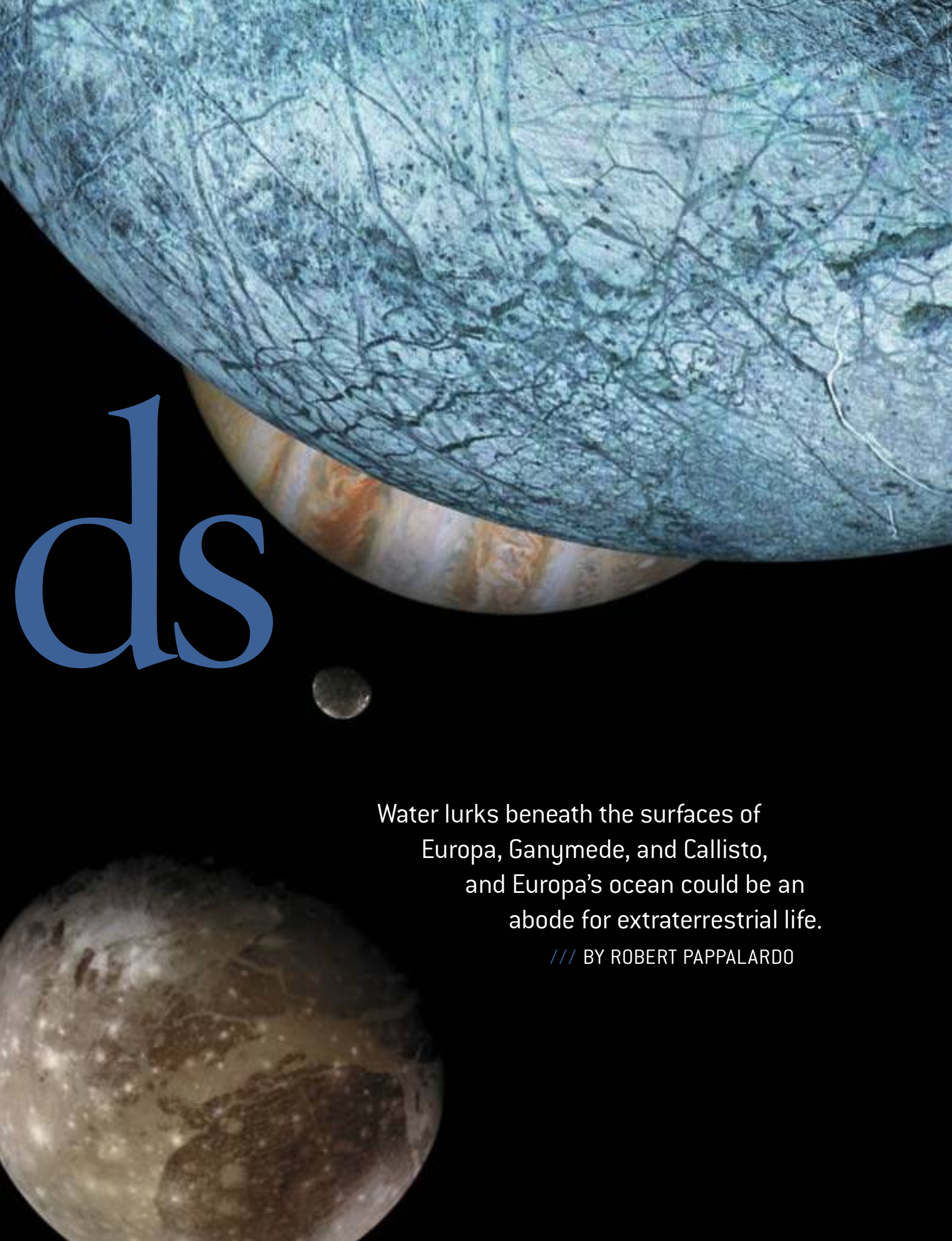
Jupiter's water worl

When the twin Voyager spacecraft cruised past Jupiter in 1979, they did more than rewrite the textbooks on the giant planet. Their cameras also unveiled the astounding diversity of the four planet-size moons of ice and stone known as the Galilean satellites. The Voyagers revealed the cratered countenance of Callisto, the valleys and ridges of Ganymede, the cracked face of Europa, and the spewing volcanoes of Io. But it would take a spacecraft named for Italian scientist Galileo, who discovered the moons in 1610, to reveal the true complexity of these worlds and to begin to divulge their interior secrets. Incredibly, the Galileo data strongly suggest that Jupiter's three large icy moons (all but rocky Io) hide interior oceans.

THREE OF JUPITER'S FOUR GALILEAN MOONS — Europa, Callisto, and Ganymede (top to bottom, with Jupiter below Europa) — apparently harbor vast oceans under their icy skins. NASA/JPL



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Water lurks beneath the surfaces of Europa, Ganymede, and Callisto, and Europa's ocean could be an abode for extraterrestrial life.

/// BY ROBERT PAPPALARDO

WATER LURKS BENEATH the surface of each of the three outer Galilean satellites. Scientists modeled the interiors based on gravity and magnetic field measurements made by Galileo. Ganymede and Europa have metallic cores surrounded by rocky shells, in turn surrounded by shells of ice or liquid water and an icy skin. Most of Callisto's interior is a mixture of rock and ice, which is surrounded by a salty ocean. NASA/JPL

Crumbling Callisto

Viewed from afar, Callisto appears heavily cratered, with few signs of internal activity. Debris from asteroids and comets in orbit around the Sun has bombarded its dark surface, with the largest impacts forming giant bull's-eye-like rings. The biggest of these, named Valhalla, was created in a gigantic collision that took place more than 4 billion years ago. As slushy ice flowed inward to fill the enormous hole, Callisto's cold, brittle skin was dragged inward as well, fracturing into a series of concentric rings.

The process of sublimation, which occurs when solid material turns directly into gas, best explains the origin of this rubbly surface. A mixture of ice and rock delivered by colliding comets and ice-rich planetesimals can sublimate slowly over time, leaving dusty debris behind. Accumulating dust, levitated by static electricity as if floating on a magic carpet, then can trickle downhill. Some tongues of dark debris attest to landslides that once roared downhill into craters. It seems that ice sublimation and downhill sliding are the chisels that have sculpted Callisto's landscape, and they still may be slowly changing its face today.

The spectral fingerprint of Callisto shows a surface with widespread clays. Hints of carbon and nitrogen compounds, the kinds of organic molecules that may have been precursors to life on Earth, also are present. Through the eons, comets and asteroids have rained organic-rich debris onto Callisto and the other jovian moons.

Some of the most startling findings about Jupiter's icy moons come from measurements that peered indirectly beneath their skins. Each time Galileo soared by a Galilean moon, mission controllers precisely tracked the spacecraft's velocity by measuring the Doppler shift of its radio signal. Changes in velocity measured the gravitational pull of each moon, which is related, in turn, to the distribution of ice, rock, and metal within.

> Far beneath the crumbling countenance of its dark surface – and forever inaccessible to humans – the seas of Callisto still stir.

Up close, Callisto's dark surface appears as a smooth fog that cloaks the moon's contours. Bright knobs poke through the shroud like islands from a dingy sea. Callisto's craters run the gamut from fresh to ruined, the latter looking moth-eaten and craggy. Their bright rims resemble the bouldery remains of ancient stone circles; their interiors brim with dark debris.

Of the Galilean satellites, Callisto's ancient, cratered surface should hold the most pristine and primitive material, the stuff from which the moons were built. Galileo's infrared spectrometer confirmed water ice exists in Callisto's bright areas, and it found carbon dioxide ice resides in some bright, fresh impact craters. Carbon dioxide leaking from dry ice buried just under the surface can explain Callisto's thin atmosphere, which is just 7.5 quadrillionths as thick as Earth's.

The gravity studies suggest that Callisto is a mix of rock and ice deep into its interior and that its constituents are only partially segregated. This implies that the moon's innards never melted throughout, somehow staying relatively cool as Callisto accreted in the ancient jovian nebula.

The magnetic field around Callisto provides another peek beneath the moon's

Robert Pappalardo, *an assistant professor in the Dept. of Astrophysical and Planetary Sciences and the Laboratory for Atmospheric and Space Physics at the University of Colorado, studies the processes that shape the surfaces of icy moons.*

surface and points to an astonishing conclusion: Callisto probably hides a subsurface ocean today. Although Callisto does not generate its own magnetic field, Galileo found that the powerful magnetic field of Jupiter induces one in Callisto. Here's how it works: The jovian field is tilted slightly to the orbital plane of the satellites, so as the giant planet rotates, Callisto bobs up and down in the jovian magnetic sea. The direction of the field as seen by Callisto correspondingly changes every few hours. As Jupiter's magnetic field effectively flips, it causes Callisto to produce an oppositely oriented magnetic field. This induced magnetic field means Callisto's interior conducts electricity. Icy innards cannot explain this; instead, the moon almost certainly contains an ocean of salty water.

Although the decay of radioactive elements left over from Callisto's formation does not generate enough heat to melt pure ice today, salts or just a bit of ammonia could play the role of antifreeze. As pressure increases within Callisto, common ice like that found in our freezers is transformed into more compact forms. Callisto's ocean would lie about 110 miles (170 kilometers) into the moon, at the boundary between ice that floats on water and ice that sinks. Far beneath its crumbling countenance, the seas of Callisto still stir, but this deep ocean will remain forever inaccessible to humans.

Ganymede's grandeur

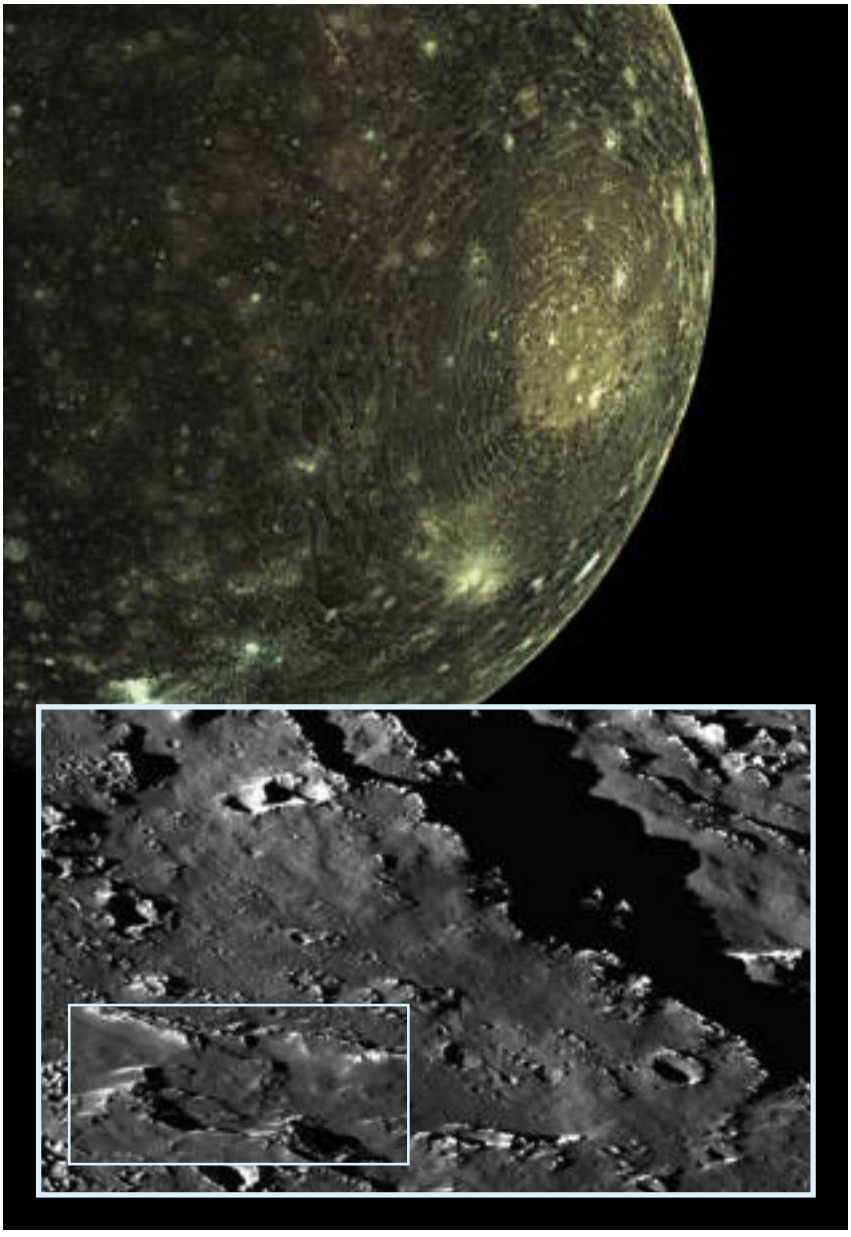
The Galilean moon named for a beautiful young prince better conveys the turbulent life of an old man, with faults and fractures laid out like dark creases on its brow. The Voyager spacecraft recorded Ganymede's diverse expressions: furrowed dark terrain, bright grooved terrain, impact craters and ghostly palimpsests, and milky polar hoods. But the moon holds even greater surprises within.

Ganymede's dark terrain is densely pockmarked with impact craters, some nearly as old as the solar system itself. Furrows arc across this terrain, and many of them trace the outlines of roughly concentric circles reminiscent of the giant, impact-induced bull's-eyes on Callisto. Close-up images suggest the terrain is darkened by a clay-rich veneer draping a brighter, icy substrate.

Impact scars on Ganymede have a range of shapes. Some are surrounded by a low pedestal that surged outward from the impact site. Some show a central pit or dome. Others are ethereal, bright patches termed palimpsests, named for reused parchment from which older writing has been incompletely erased. Like partially visible ancient text, traces of Ganymede's furrows sometimes can be discerned within the palimpsests. The palimpsests probably formed when ancient, large impacts pierced a thin and brittle icy shell, splashing slushy ejecta onto the surface.

Generally, the more heavily cratered a planetary surface, the older it is because it has had more time to accumulate impact scars. Compared with the dark terrain on

/// CALLISTO'S CRATERED SURFACE



AN ENORMOUS COLLISION more than 4 billion years ago created the multi-ringed structure on Callisto called Valhalla (top, at right). The central, smooth patch is as large as the state of Colorado, while the entire basin spans 2,500 miles (4,000 km). **A PROMINENT FAULT SCARP** (above) cuts across Callisto's Valhalla region. The many craters testify to the structure's great age. **A CRATER CHAIN** (inset) formed when a split comet slammed into Callisto billions of years ago. The comet likely resembled the more recent Shoemaker-Levy 9, which broke apart before crashing into Jupiter in July 1994. NASA/JPL

Ganymede, the more sparsely cratered grooved terrain indicates relative youth. Depending on the uncertain rate at which asteroidal and cometary debris has pummeled Ganymede over the eons, age estimates range from hundreds of millions to as many as 4 billion years old.

The parallel ridge and valley sets comprising grooved terrain crisscross Ganymede's bright regions. Tens of kilometers wide and hundreds long, these corrugated swaths split the older, dark terrain into polygonal tracts. The alternating valleys and ridges on Ganymede resemble the scratches in a plowed field. Their shapes and relationships to one another tell scientists that the grooves formed chiefly through stretching of the moon's icy skin. Unlike compression, which created the accordion-like folds seen in mountain ranges like the Appalachians on Earth, pulling apart can create long valleys or rotate and tilt slabs into pointed mountains.

the magnetic field implies convection in a partially molten metallic core.

Galileo's gravity measurements confirm this story, showing that so much of Ganymede's mass is concentrated near the center that the moon must have a metallic core. Intense heating once melted Ganymede's ice, creating an internal flood. The moon's icy matrix then released its rock, which sank down to form a solid mantle, while water floated up and chilled into an icy skin. The moon's innards became so hot that metals melted out of the rocky mantle, sinking deeper to form an iron-rich core. Ganymede's existing magnetic field tells us that the moon has not yet completely cooled off from its period of intense activity. Heating, differentiation, and surface tumult may have occurred late in solar system history, perhaps merely a billion years ago. Like Callisto, Ganymede has an induced magnetic field as well, pointing to a salty ocean that flows deep within the icy moon today.

are locked: Each time Ganymede revolves around Jupiter once, Europa revolves twice and Io, four times.) This powers continuous volcanic eruptions on Io and probably maintains a liquid ocean within Europa. Although Ganymede does not receive significant tidal heating today, the satellites' orbits may have evolved, and perhaps past tidal heating triggered Ganymede's differentiation. Callisto, however, sits out the orbital dance and has never been tidally heated. Apparently, the orbital push and pull of Io and Europa have driven Ganymede and Callisto onto distinct evolutionary paths, and lined Ganymede's face.

Enigmatic Europa

Europa's surface is woven with a complex patchwork of fractures, ridges, bands, and spots. The moon's enigmatic landscape tells of a dynamic interior beneath a frigid skin of ice, and of the power of giant Jupiter, whose gravity profoundly affects this moon.

> Ganymede's grooved terrain is the frozen manifestation of the fierce internal strife that wracked the moon during its adolescent years.

The grooved terrain's brightness can be explained if water erupting from volcanic vents once covered up and erased tracts of the dark, ancient surface. However, water "magma" would be denser than surface ice, so it should sink rather than rise. Just as a shaken soda bottle froths when opened, dissolved gases might drive a bubbly slurry upward to erupt, or perhaps warm glacial ice under the grooved terrain was able to rise buoyantly toward the surface.

The ubiquity of grooves implies the entire moon expanded during Ganymede's adolescent years. Grooved terrain tells of fierce internal strife and is perhaps the imprint of heating, differentiation, and expansion. The grooved terrain we see today is the frozen manifestation of a violent past.

Galileo completely surprised planetary scientists when it discovered an internally generated magnetic field at Ganymede. Although the field's strength is only about 1 percent of Earth's, it is strong enough to carve out its own magnetospheric bubble within Jupiter's much larger magnetosphere. The internal dynamo that creates

Ganymede's internal magnetic field deflects charged particles trapped in Jupiter's immense magnetosphere and funnels them onto the moon's polar regions. Crashing down, they can damage ice grains and redistribute water-ice molecules, brightening the surface to create the moon's hazy polar caps. Earth-based spectra suggest oxygen bubbles probably are afloat within individual grains of ice, miniature atmospheres trapped in ice like bugs in amber.

Galileo's gravity and magnetometer data indicate that the disparities between Ganymede and Callisto are much more than skin deep. The fundamental difference between the two moons seems to be the process of heating — and the subsequent melting and differentiation — which induced wide-scale activity on Ganymede but essentially none on Callisto.

Tidal heating most likely explains the divergence of these sibling moons. Giant Jupiter raises tides in the body of each Galilean satellite, but the orbital dance of the three inner moons constantly squeezes and heats them. (The orbits of the three

As Europa travels in its eccentric orbit, it moves closer to and farther from Jupiter with the rhythm of its 3.55-day orbit. Its icy shell is stretched and released, stretched and released, raising a tide as high as 100 feet (30 meters). This tidal tugging distorts Europa's icy surface to the point where it cracks. From the complex pattern of markings on the moon, planetary scientists can deduce how Europa has been molded.

In addition to the tidal tugging, scientists can decipher the pattern caused by nonsynchronous rotation. Like Earth's Moon, most of the solar system's large satellites rotate synchronously — each with a gaze of one hemisphere affixed toward its parent planet. But Europa seems to be a rare exception, its icy surface slipping forward very slowly relative to Jupiter's direction, with one full rotation taking as little as 10,000 years or as long as one billion years. This can happen only if something lubricates the moon's icy shell, such as a subsurface ocean. The seemingly random doodlings on Europa's complex surface nicely match the fracture

pattern scientists predict from nonsynchronous rotation.

Double ridges are Europa's most ubiquitous features — and its least understood. These unique ridges are stitched across the surface in pairs, with a narrow valley running down the center. Long fractures also scratch the surface, and it seems they are related to the double ridges. But how? One idea holds that tidal flexing as Europa orbits Jupiter pumps water and icy slush from deep fractures onto the surface, like glue squirting between repaired pottery pieces. Perhaps the fractures reach all the way down to an ocean, the presumed source of the watery ooze.

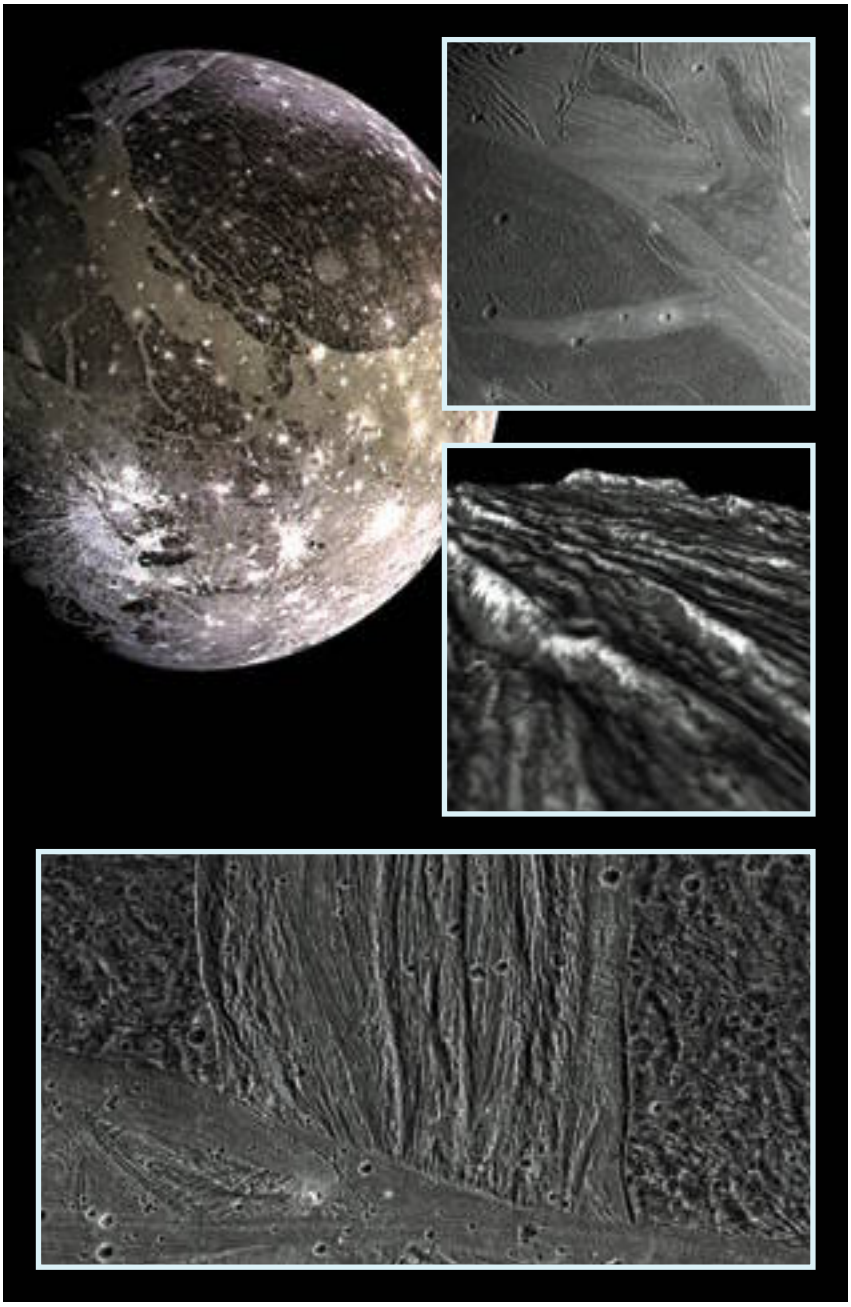
Another model invokes shallow, warm ice that rises along a crack. Like a tree root pushing up an asphalt sidewalk, the ice slab warps the surface into a double ridge. This scenario requires a crack to reach relatively warm, glacially flowing ice, but not all the way down to water. However these bizarre ridges formed, they certainly point to a geologically dynamic moon.

In many places, pits, spots, and domes freckle Europa's face. Some are places where the surface has been warped, as if pushed from below by a giant thumb. Other spots appear dark and disrupted. One puddle-like spot is ice-rink smooth, presumably the result of water flowing onto Europa's surface sometime in the past. This means the moon's interior had to be warm enough to melt ice, which offers the clearest sign of icy volcanism on any Galilean satellite. Although the surface of an icy satellite is unimaginably cold, if radioactive or tidal heating warms interior ice, the warmer ice tends to rise like blobs of wax in a Lava Lamp. Such rising blobs probably explain the spots that freckle Europa.

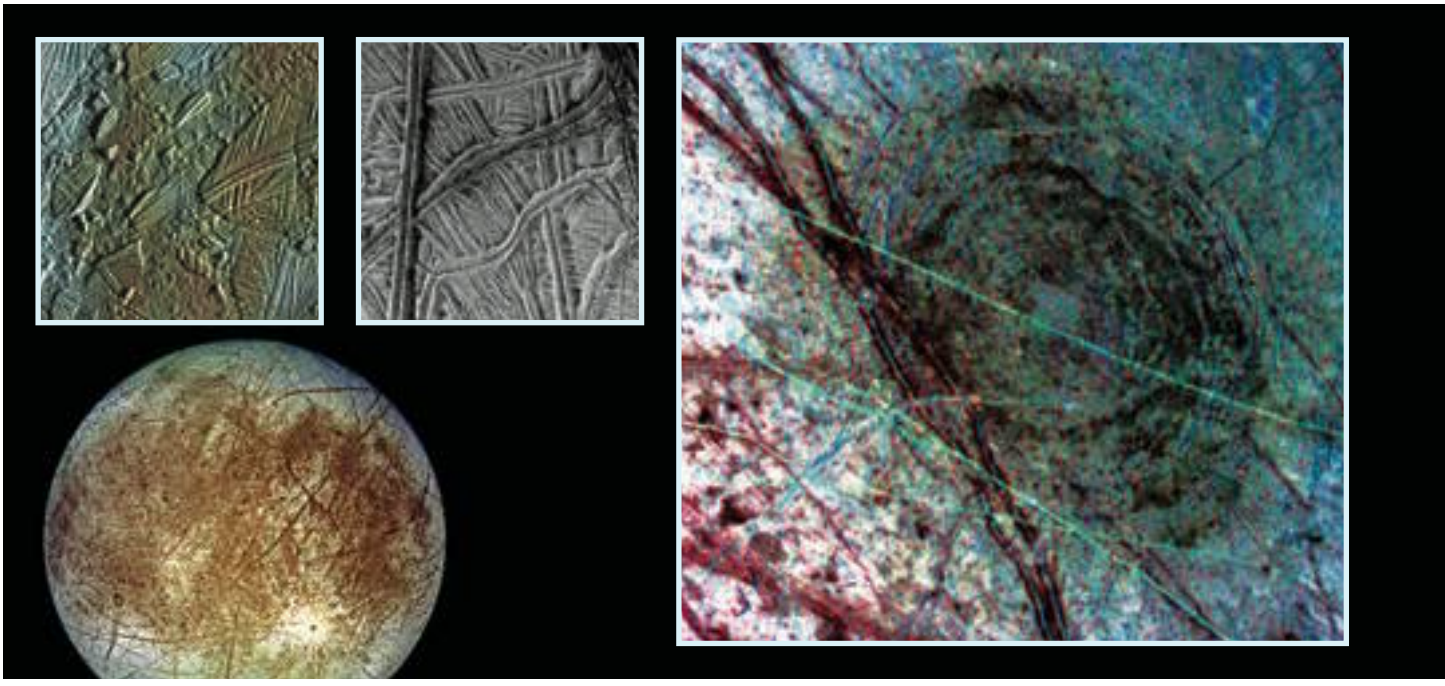
Topping the chart of Europa's most enigmatic places are areas of jumbled ice blocks appropriately termed "chaos" regions. Icy plates appear to be tilted there, like icebergs calved into a slushy sea. The matrix between the plates is a rough and jumbled expanse. Scientists have attempted to reconstruct the icebergs to their original positions in jigsaw-puzzle fashion, but half the puzzle pieces are missing — somehow destroyed — and there's no box to show how the picture should look when it's finished. On the one hand, these chaos areas might imply melting from an ocean below. On the other hand, they may have formed when blobs of warm, rising ice pushed and twisted icy blocks.

Galileo's infrared instrument showed abundant water ice on the moon, as expected. But in Europa's darker and redder regions, such as the chaos areas, the compositional fingerprints are skewed. This may be evidence that charged particles trapped in Jupiter's magnetosphere make H_3O in Europa's ice. Another suspect is some sort of salt; Europa may be the solar system's largest storehouse of Epsom salt. Sulfuric acid, which we also know as battery acid, is another possibility.

/// GANYMEDE'S MOTTLED SURFACE



GANYMEDE'S GROOVED TERRAIN (top) suggests the entire moon expanded sometime in its history, after tidal heating warmed its interior. **STEREO IMAGING** (middle) helped unravel the first close-up images. In this exaggerated-relief view, small ridges and grooves are superimposed on broader valleys and swells in bright terrain. **BRIGHT RIDGES** in Sippar Sulcus (at bottom of the lowest image) cuts the older grooved terrain of Erech Sulcus. Both of these features slice across the even older terrain of Marius Regio. NASA/JPL



THE ICE PLATES of Conamara Chaos (top, left) appear to float in a lumpy matrix like icebergs afloat in a polar sea. Such areas sparked the debate over the existence and nature of a Europan ocean. **EUROPA'S RIDGED PLAINS** (top, middle) were photographed when the Sun was high in the sky, revealing their pale beauty. Ridges about 0.6 mile (1 km) across slice older ridges and bands. **A LARGE IMPACT** scarred Europa (above, right), fracturing the surface minutes after a mountain-sized asteroid or comet slammed into the moon. NASA/JPL

Although sulfuric acid is colorless, it could provide an important clue as to why Europa's dark areas appear reddish. The harsh, charged particle radiation that bathes Europa would quickly kill a human, ripping apart cell walls and life-sustaining chemical bonds. Unwary molecules of sulfuric acid likewise would be torn into their constituent parts, liberating sulfur, which, in turn, can combine with other materials to form long molecular chains. These sulfur chains are a ruddy ocher color, which possibly explains Europa's blush. Sulfuric acid itself could be a product of radiation bombardment, formed by the breakdown and recombination of ice and sulfur dioxide (SO_2), a frost that has been detected on Europa.

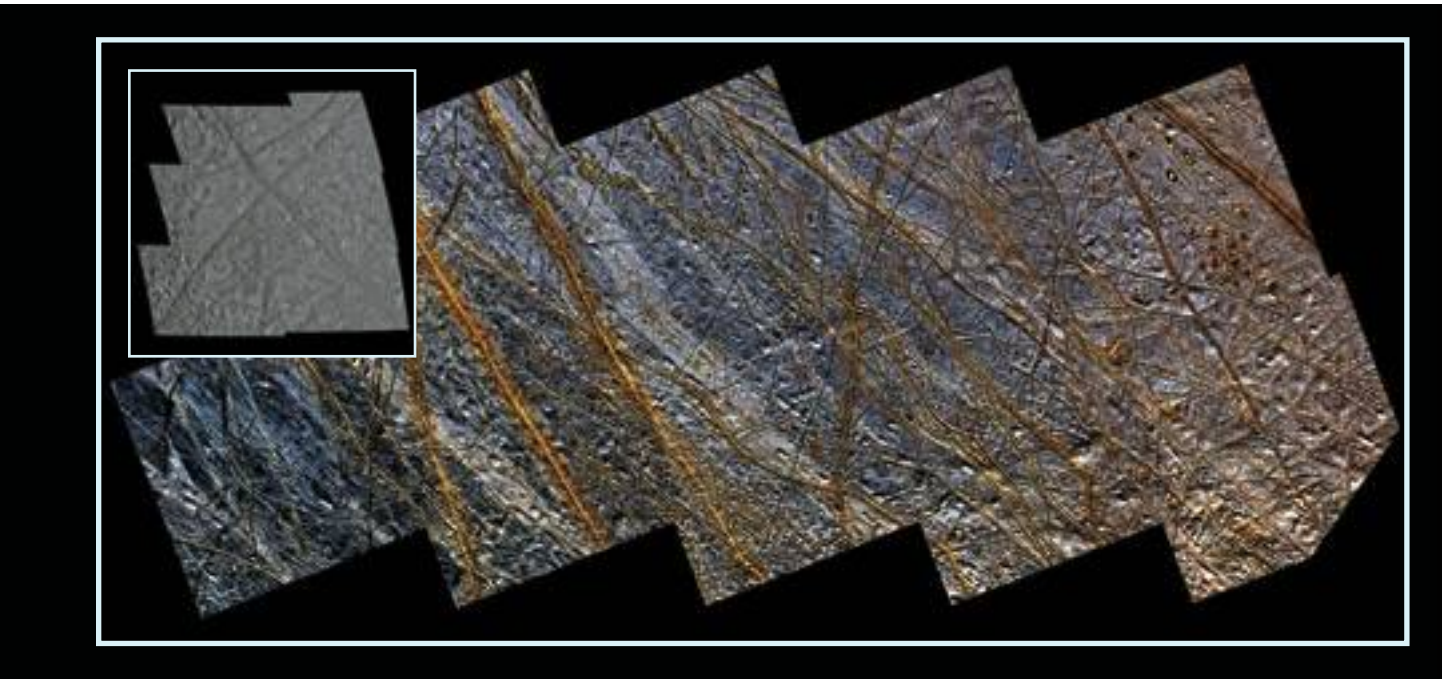
The paucity of large craters shows Europa's surface to be remarkably young. From predictions of the number of comets that should have hit Europa over time, the moon has been completely repaved in the past 60 million years. All the satellite's ridges, bands, and chaos regions have formed in the brief time since dinosaurs disappeared from Earth. While a lot can happen in 60 million years, this is a blink of an eye by planetary standards.

Close-up photos of Europa's Tyre impact site show a central, smooth patch surrounded by concentric rings, much like a miniature version of Callisto's Valhalla. The impact blast that made Tyre must have penetrated through the cold near-surface ice into a weaker layer below. Considering the depth to which the Tyre impact could have dug, the liquid or weak slushy layer must be only about 13 miles (20 km) deep within Europa.

Galileo's gravity measurements indicate Europa probably has an outer layer of H_2O about 60 miles (100 km) thick above a thick, rocky mantle and a central, iron-rich core, but gravity data cannot tell scientists whether any of this H_2O is liquid. If most of the water layer is liquid, its volume would be twice that of all Earth's oceans combined.

> Europa's ocean of liquid water may be eternal and deep, maintained by the ceaseless warming power of Jupiter's gravitational tug.

The most bizarre features of Europa's landscape menagerie are ridges that look like sets of repeating, bow-shaped arcs. The Voyager spacecraft discovered these mysterious ridges, and Galileo found many more. For twenty years, Europa's ocean had been calling to us, too cryptic in its cry. Then, Randy Tufts and Greg Hoppa of the University of Arizona realized that Europa's tidal flexing can explain these cycloidal shapes.



X MARKS THE SPOT (inset) of the region named Conamara Chaos on Europa. The 60-mile-wide (100 km) region lies just below the X created by intersecting ridges in this image. The icy surface in this area has been broken into several separate plates, which have moved laterally and rotated. Pits, spots, and domes pepper the area. **BROWNISH DOUBLE RIDGES** (above) that extend across Europa's surface likely are the frozen remnants of water eruptions onto the surface. The colors in this image have been enhanced to bring out the details. NASA/JPL

As Europa orbits Jupiter, the rise and fall of the moon's tidal bulge bends and stretches the icy shell to the point where it cracks. While this is happening, the direction in which the tides pull changes continuously. Some cracks follow a curved path instead of a straight line, tracing out one arc with each Europan orbit. With this computer model, Tufts and Hoppa could reproduce the shapes of Europa's arcuate ridges almost perfectly.

These ridges are the call of a hidden ocean. If Europa's interior were solid ice, then Jupiter's gravity should raise a tide only 3 feet (1 meter) high, and the small amount of stress would not be enough to make the surface crack. But if Europa hides an inner ocean, the moon's icy rind should rise and fall by 100 feet (30m) during each orbit around Jupiter. An ocean facilitates the formation of cycloidal cracks and ridges, so their very existence argues for a sub-ice ocean.

Confirmation of this idea comes from magnetic measurements, like those made at Callisto and Ganymede. The sum of the theoretical and observational evidence tells of an ocean within Europa, probably within about 15 miles (25 km) of the surface, above a denser, saltier ocean nearly 60 miles (100 km) deep.

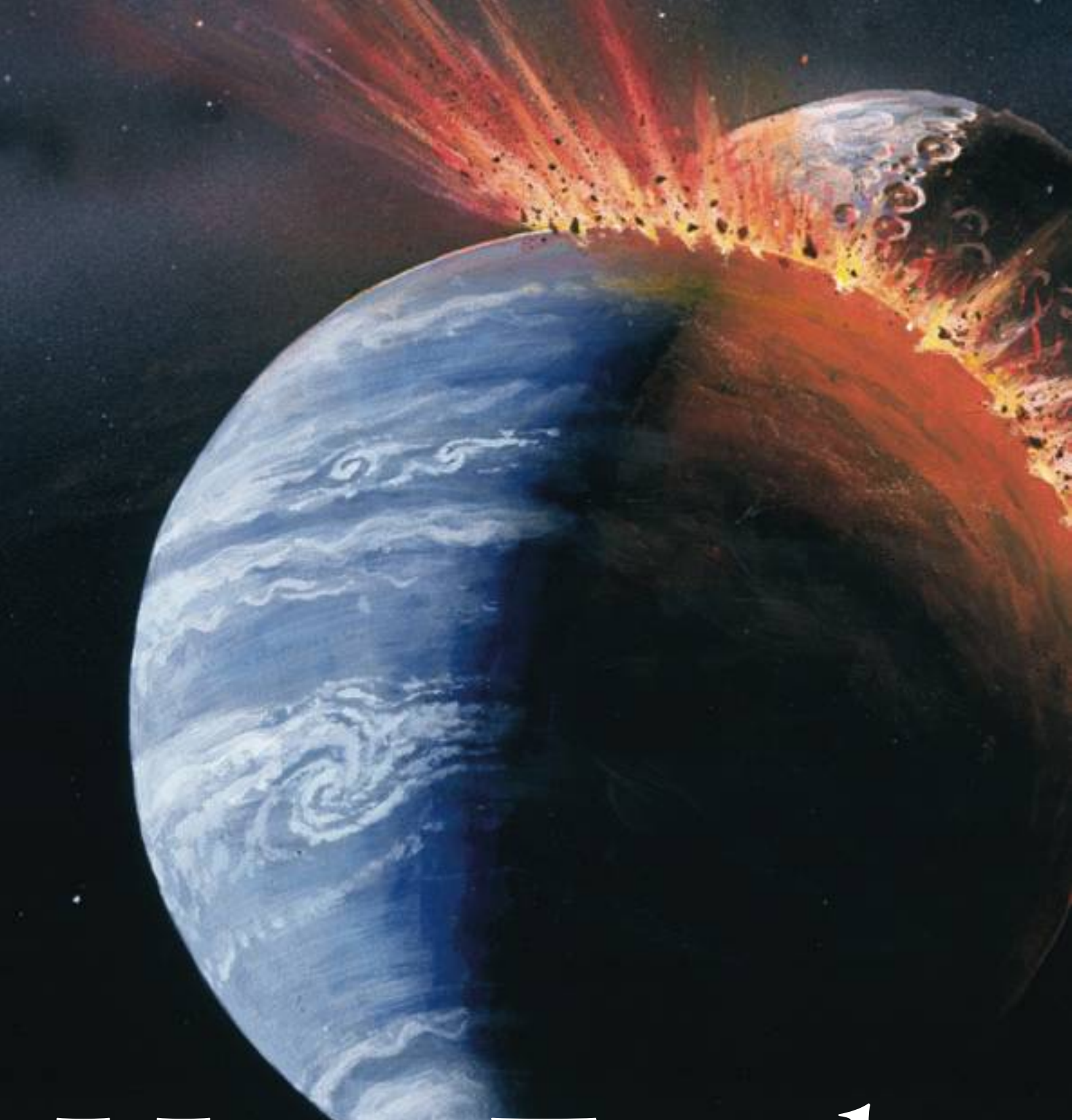
Abodes of life?

The Galileo spacecraft was not designed to divine subsurface water. Thanks to its unexpected observations and some clever scientific analyses, the weight of the evidence suggests that all the icy Galilean satellites possess oceans within. The oceans of Ganymede and Callisto are probably vestiges of warmer pasts, slowly freezing closed today. But Europa's ocean may be eternal and deep, maintained by the ceaseless warming power of Jupiter's gravitational tug. On Earth, everywhere there is water, there is life. Thus, if clues point to brackish water beneath the surfaces of Jupiter's three icy moons, we might stretch our imaginations far enough to ask whether life might have arisen within the briny depths not only in the realm of Jupiter, but within icy moons throughout the universe.

The future will bring new spacecraft to explore the water worlds of Jupiter. Currently on the drawing board is NASA's Jupiter Icy Moons Orbiter (JIMO), slated for launch in the middle of the next decade. This mission would be powered by a nuclear reactor and an ion drive, which would provide sufficient thrust for the spacecraft to orbit each of the icy Galilean moons in turn. Orbiting the moons would allow for direct measurement of their tidal fluctuations, a definitive test for hidden oceans. The moons would be scoured by cameras and spectroscopes, and their subsurfaces would be probed with radar. A small lander might even examine Europa firsthand.

Europa's recent and possibly current activity means the moon might have sources of chemical energy to power life, making its ocean the most likely abode for extraterrestrial life in the solar system today. Exploration of the water worlds of Jupiter has the potential to bring about a revolution in our understanding of the universe not experienced on this planet since Galileo turned his telescope skyward and first spied these moons. A

To learn more about the proposed JIMO mission, visit www.astronomy.com/toc



How Earth g

Many people think of Earth and its Moon as a double planet, but the pair strikes scientists more as an odd couple. Even the "double" part, they've found, is oddly ironic. /// BY PAUL D. SPUDIS

...got its Moon

TO JUDGE BY ITS NEAREST NEIGHBORS, the Earth-Moon system is different — you could even call it strange. Venus, a nearby rocky planet, revolves around the Sun alone; no moon brightens its cloudtops. Mars has two little rock-like satellites, Phobos and Deimos, but each is smaller in size than the craters visible in the smallest telescopic views of our Moon. And then there's Mercury, with a cratered surface that looks like a big Moon, while its inside resembles a little Earth with an enormous iron core. But just like Venus, Mercury travels alone and moonless.

Yes, something about our corner of the solar system looks different. Earth has a moon and it's huge, relatively speaking. The words *double planet*, often used to characterize Earth and the Moon, make an interesting term, one that embodies an ironic truth.

In the years before and immediately after the Apollo missions, no single idea for the Moon's origin was accepted by scientists. The three traditional models of lunar origin all were thought to be flawed in one sense or another. The "capture" model held that the Moon formed elsewhere and was snagged into Earth's orbit during a glancing, near-miss encounter. The "fission" model suggested the Moon was ripped out of Earth's body, splitting into a double-planet system like a reproducing amoebic cell. The "co-accretion" model theorized Earth and the Moon formed in the same part of the solar system but as separate planets, independent of each other before joining gravitationally.

Some hard facts about the Moon were known before we went there, but no idea fully fit its observed properties and inferred history. For example, the Moon's average density is much lower than Earth's — 3.3 times that of water compared to Earth's 5.5 times. However, the lunar density comes close to the density of Earth's mantle, the rocky portion sandwiched between the light outer crust and the dense inner core.

The Apollo missions proved that Earth and the Moon are closely related — oxygen isotopes of lunar samples show the Moon formed in the same general region of the solar system as Earth. The samples also indicate the Moon has a low content of volatile elements, suggesting its birth involved high temperatures that would have destroyed such elements. What struck scientists as weird, however, was that while the Moon's chemistry most closely resembles Earth's mantle, the mantle is a *secondary* feature of our planet's evolution. It emerged when Earth, soon after formation, differentiated into mantle and core. How could any kind of moon, born as an independent body, have a composition matching the mantle?

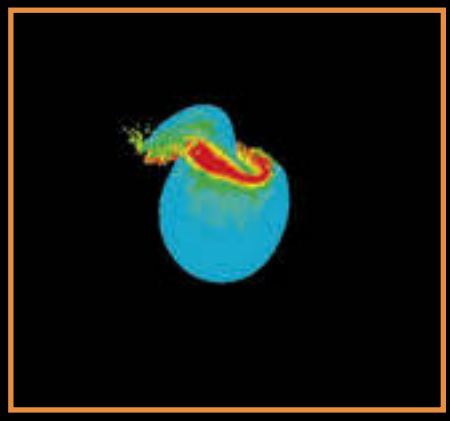
Scientists tend to solve their knottiest problems while working on ones believed to be totally different. Some key clues to the origin of the Moon

EARTH AND ITS MOON form a unique pair in this part of the solar system. Evidence suggests they were created in the aftermath of a gigantic impact between two other objects. ILLUSTRATION BY WILLIAM K. HARTMANN

/// SIMULATING A GIANT IMPACT

Smashing planets together in a computer allows scientists to construct a likely scenario for the origin of the Moon and Earth. A Mars-size impactor hits the proto-Earth a glancing blow, shooting debris into orbit. This later coalesces into the Moon. In the simulation, colors show the temperature range. Medium blue is 2,000 kelvins (3,600° Fahrenheit), while red is 7,000 kelvins (13,000 °F). The final frame (page 47) shows the Earth-Moon system edge-on.

ROBIN CANUP/SWRI



THE FAMILIAR FACE of the Full Moon shows the dark maria and bright highlands. The highlands are made mostly from an unusual rock that formed as a scum on the surface of a global ocean of molten rock. *CONSOLIDATED LUNAR ATLAS* PLATE Y842

involved evidence from two, seemingly unrelated, problems: the origin of small, white pebbles in the dark soil of the Apollo 11 landing site, and the mapping and measurement of ancient impact basins on the Moon.

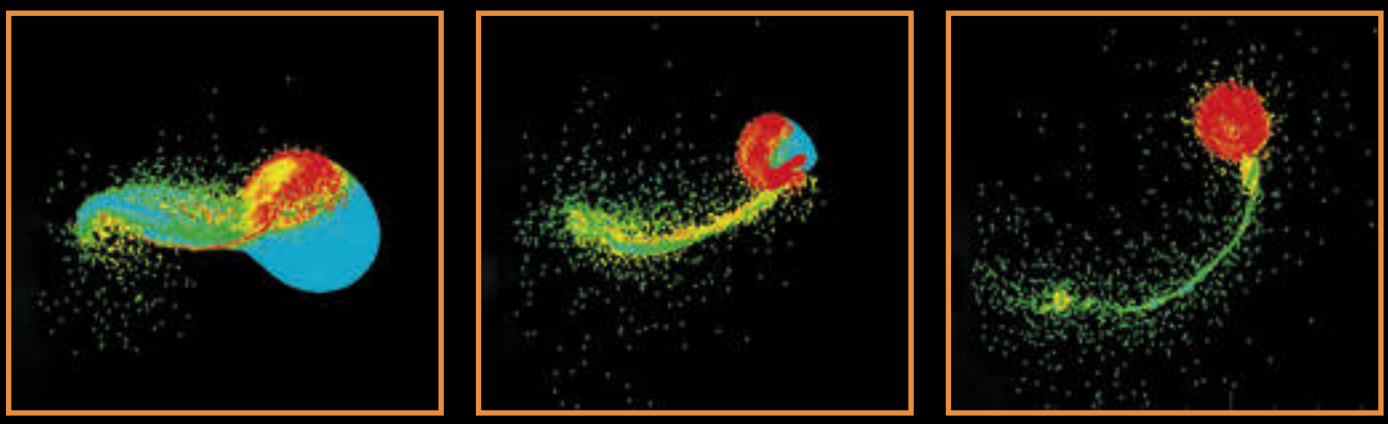
White stones

Small fragments of white rocks contained in the soil collected and returned by the Apollo 11 astronauts suggested the highlands (the bright, rugged uplands of the Moon) are made of an igneous rock type called anorthosite. This rock cooled from an initially molten state and consists almost entirely of the light-toned, low-density mineral plagioclase feldspar.

Making rocks composed of a single mineral is not easy because nature tends to mix things. In this case, the difficulty is compounded by the fact that no known kind of magma (molten rock) has a composition corresponding to anorthosite. Worse was the sheer quantity of anorthosite found on the Moon. From the Apollo data, it was evident that anorthosite and similar rock types make up much of the lunar crust. That's a lot of rock to explain.

The solution lies in the low density of plagioclase compared to other common lunar minerals. A Moon encircled by an ocean of liquid rock would soon develop a film on its surface — a skin of plagioclase crystals floating on a magma made of the lunar bulk composition. As this magma ocean cooled, the film thickened into the rock anorthosite, creating a plagioclase-rich upper crust. Similarly, the high-density, iron- and magnesium-rich minerals olivine and pyroxene sank, accumulating at the bottom of the magma ocean. Thus, the magma ocean solidified from two directions, thickening downward as the anorthositic crust grew, and building upward as olivine and pyroxene crystals settled to the bottom of the sea of molten rock to form the lunar mantle.

This basic story was reasonably well understood shortly after the Apollo program ended in the early 1970s. However, questions lingered about the source of heat that created the magma ocean in the first



place. A very rapid pace of accretion could help answer that question. But was such a fast pace possible when all existing studies indicated the planets took a considerable time to accrete? The problem of accounting for the magma ocean's heat source caused some investigators to abandon the idea altogether. Then came some new thinking about the bombardment history of the early planets.

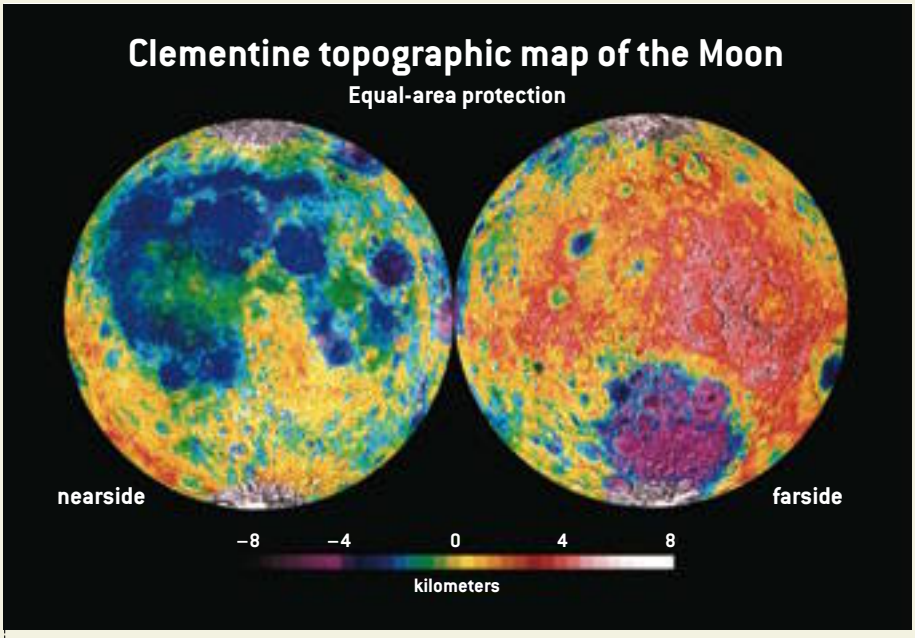
Biggest basin

At the time the magma ocean existed, Earth and the Moon were coalescing out of debris left over from planetary formation. In the Moon's case, we can still see a record of the tail end of this early bombardment with even a small telescope: the rough, heavily cratered face of the ancient highlands. Geologic mapping done to support the Apollo missions led planetary scientists to recognize that craters exist in a continuous spectrum of size from microscopic to thousands of miles across. Detailed mapping, however, showed the largest crater appeared to be on the Moon's farside. But the structure was glimpsed only briefly from orbiting Apollo spacecraft (and poorly photographed), so its size and nature remained vague.

The feature was named the South Pole-Aitken basin (SPA) from two unrelated, superimposed features. It appears noticeably darker than the rest of the generally bright farside. In 1990, pictures returned by the Galileo spacecraft revealed the basin has a distinct composition, while its dark appearance suggests the basin floor is made of rocks rich in iron. In fact, scientists eventually concluded the floor might be the lower crust of the Moon, exposed after a gigantic impact stripped off the anorthosite-rich upper crust.

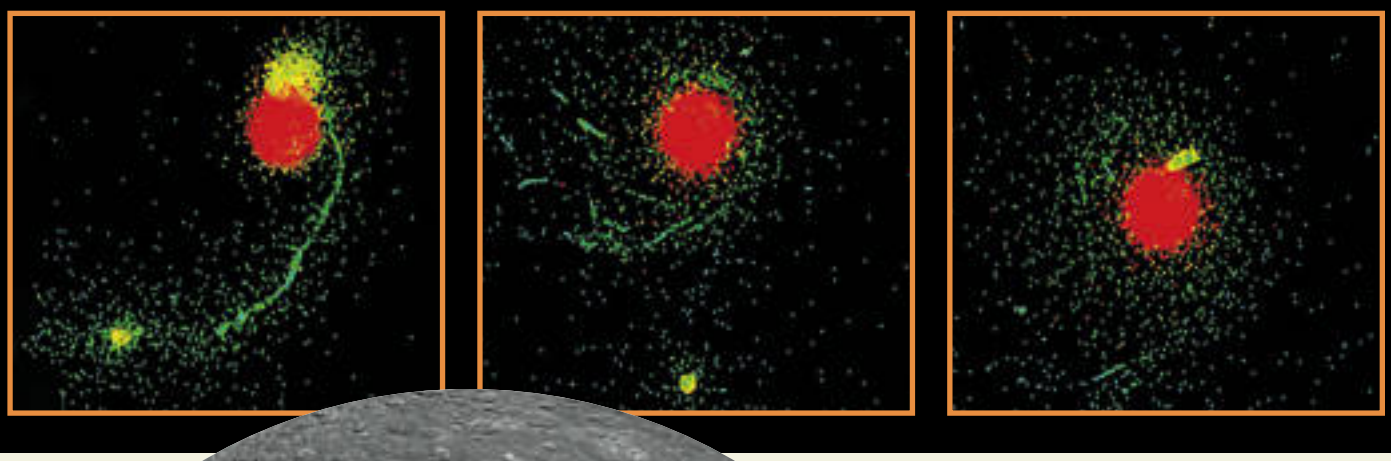
In 1994, the Clementine spacecraft's laser altimeter made a global topographic map of the Moon, revealing the basin's true nature and extent. It spans more than 1,500 miles (2,500 km) — the distance between Houston and Los Angeles — and ranges from 5 to 8 miles (8 to 13 km) deep. SPA is the oldest surviving impact basin on the Moon. Mineralogical mapping by Clementine (and the Lunar Prospector spacecraft a few years later) showed that SPA has a composition unmatched anywhere else on the Moon.

The discovery of this feature was a key piece of evidence in the search for the Moon's origin. The basin's large size shows that big, planetary-scale collisions actually occurred. Such impacts had scarcely been imagined, let alone modeled scientifically. Yet subsequently, many computer simulations have shown possible outlines for the origin of the Moon.



LUNAR UPS AND DOWNS stand out starkly in the laser altimetry carried out by the Clementine spacecraft. The maria on the nearside all lie below lunar "sea level" — as does the South Pole-Aitken basin on the farside. ACT CORP./ LPI/UNIVERSITY OF HAWAII

Paul Spudis *is a planetary scientist at the Applied Physics Laboratory of Johns Hopkins University. He is the author of* The Once and Future Moon, *published by the Smithsonian Institution Press. His latest book is* The Clementine Atlas of the Moon, *published by Cambridge University Press.*



THE LUNAR FARSIDE contains mostly light-colored highlands. But the big, dark patch at lower center shows where the South Pole-Aitken excavated through the light-colored upper crust, exposing the darker, iron-rich lower crust. U.S. GEOLOGICAL SURVEY CLEMENTINE IMAGE MOSAIC

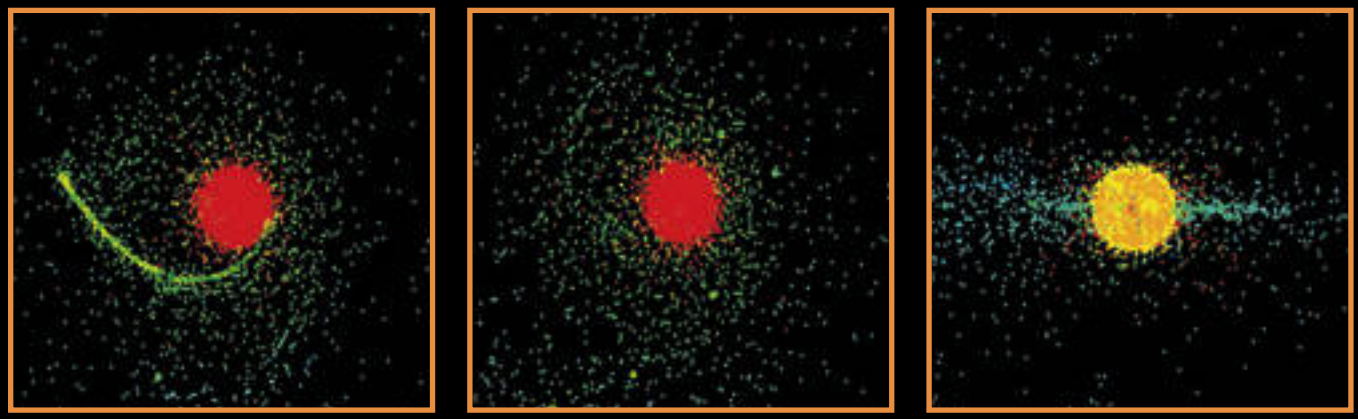
1 + 1 = 1 + 1?

Planetary scientists now believe that 4.6 billion years ago, at least two planets existed in the space now inhabited by Earth. One was a protoplanet about the size of Mars, while the other was a proto-Earth, with 50 to 90 percent its present size and mass.

The model works best when the proto-impactor hits Earth with an oblique blow that reinforces its existing spin. Such a collision would have several effects. First, the off-center hit speeds up Earth's rotation. Second, the mantles of both impactor and proto-Earth are vaporized by the energy of the impact. Third, most of the impactor's mass bounces off the proto-Earth; it flies in a ballistic path that brings it back to reaccrete onto Earth's surface sometime later. Finally, a quantity of vaporized debris, mostly from the mantle of the proto-impactor (with some proto-Earth mantle as well), shoots into orbit around Earth. This white-hot material cools very quickly, turning into a disk of fine debris. In the giant impact's immediate aftermath, Earth resembled a chaotic Saturn, at least for a time.

Such a disk has no stability, however. After the loose particles migrate outside the point where tidal stresses prevent them from coalescing, they accrete quickly into a moon. Estimates of the accretion time scale range from a few to several thousand years, very rapid in geological terms. The energy of accretion appears as heat that cannot easily dissipate — and the result is a body that melted almost totally.

Still, details of the Moon's assembly remain imperfectly understood. Did it occur all at once, as a myriad of small objects combined into a fully formed Moon, or did a group of smaller sub-moons form first and then smash together? The Moon has several global asymmetries. For example, the nearside and farside differ in how much mare they possess, and the eastern and western halves of the nearside show compositional differences. Perhaps these variations reflect an early series of large impacts, each being the merger of many sub-moons into a growing, rapidly evolving new planet that we might call Luna.

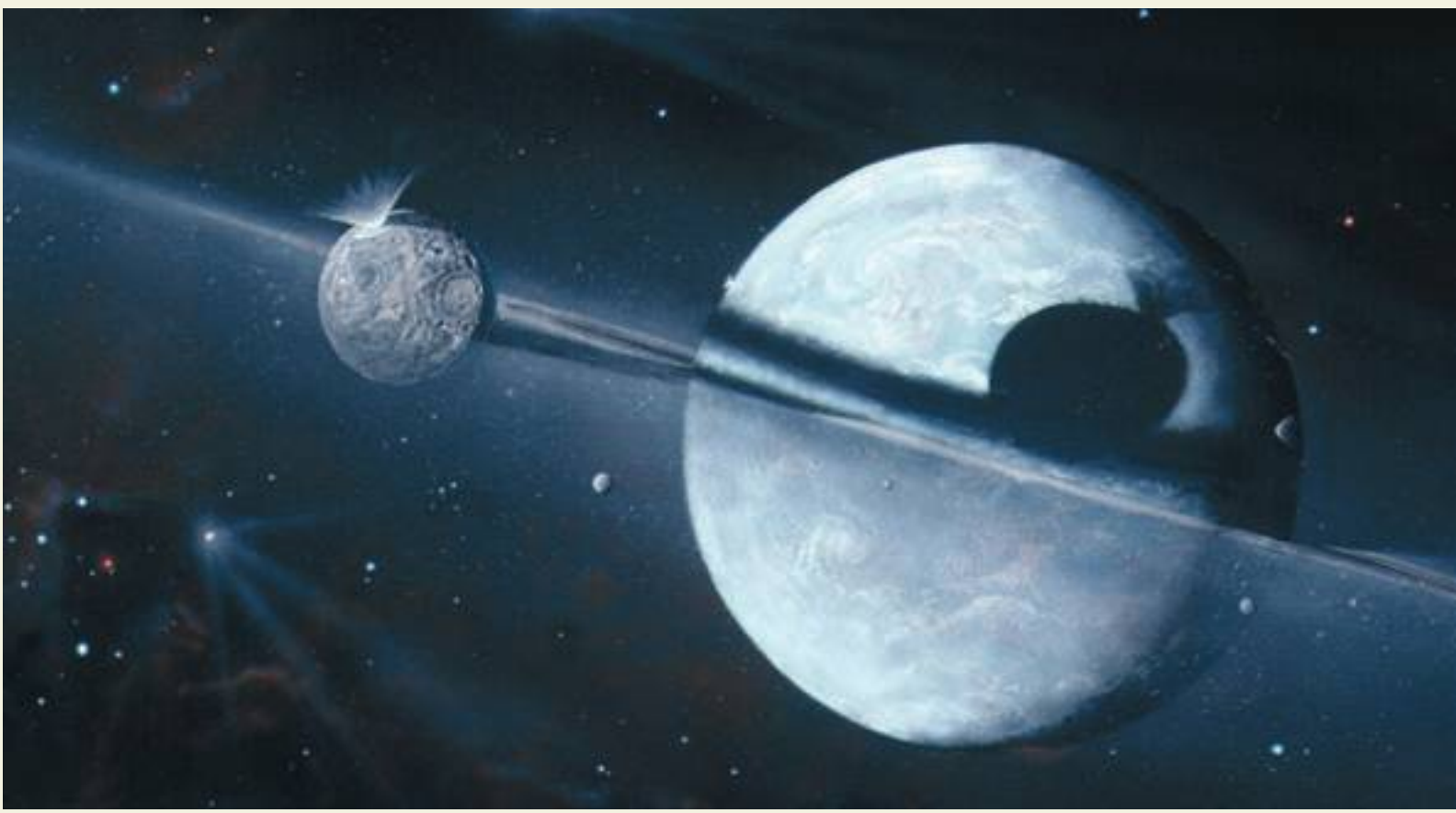


Double planet

Therefore, the old adage about Earth and the Moon being a double planet masks a subtle irony. Yes, they are a double planet — but they are the *second* double planet to orbit here. After the first two collided in a giant impact, a new planetary pair formed — Terra and Luna. These two worlds, each with its own fascinating history and evolution, are closely linked by a deep-seated planetary kinship. Our geologically active Earth has erased most clues of its very early history. But the story of our system's violent birth, global melting, and impacts of unimaginable intensity is coming to light as scientists study lunar rocks and global maps of the Moon.

Separated at birth but reunited by chance, these two worlds dance together across the solar system. The original two worlds that collided here 4.6 billion years ago no longer exist. They merged, forming a unique system — a pair of bodies no longer orbiting the Sun independently, but a true double planet, bound together by gravity, history, and geochemistry. A

To learn more about making the Moon, visit www.astronomy.com/toc



THE DOUBLE PLANET Earth and Moon cool off after their birth pangs, 4.6 billion years ago. The ring of debris shown orbiting Earth indicates the process of accretion is still going on for both bodies. ILLUSTRATION BY WILLIAM K. HARTMANN

Did NASA fake the moon landings?

To quash any lingering doubts as to whether or not we went to the Moon, *Astronomy* is setting the record straight, once and for all.

/// BY RAY VILLARD

The seven Project Apollo manned expeditions to the Moon will long be remembered as expressions of America's pioneering spirit and sheer technological prowess. That is, if the landings really happened.

For the past several decades, a small group of NASA-watching sleuths has repeatedly tried to pawn off the incredulous idea that the Apollo Moon program really was an elaborate, $30 billion hoax filmed in a movie studio. This group believes the United States needed to cement its world leadership during the Cold War by pretending to pull off what really was a technologically impossible stunt. Moon hoax proponents think they've come up with suspicious evidence that scientists, investigative reporters, and everyone else on Earth apparently has overlooked for more than thirty years. The far-out idea drew 15 million viewers when FOX-TV twice ran a documentary on this subject in 2003.

Seeds of doubt

In the October 30, 1938, theatrical radio adaptation of H. G. Wells's *War of the Worlds*, actor Orson Welles managed inadvertently to convince 1.2 million Americans that martians were invading Earth. So, for conspiracy theorists, it's easy to imagine that with $30 billion and the awesome power of the United States government, the world could be made to believe almost anything. If Hollywood can fake perfectly believable dinosaurs, space aliens, and fantasy planets, why not a visit to the Moon?

A former aerospace technical writer, Bill Kaysing kicked off the Moon conspiracy idea in 1975 in a self-published book with the blunt title *We Never Went to the Moon*. Several copycats have followed him — *Moongate: Suppressed Findings of the U.S. Space Program* by William L. Brian (1984), Ralph Rene's *NASA Mooned America* (1994), and *Dark Moon-Apollo and the Whistle Blowers* by Mary Bennet and others (1999).

But don't expect to find these books on *The New York Times* best-seller list. According to a 1999 Gallup poll, an inconsequential 5 percent of the population in the United States actually believes we never went to the Moon. (Coincidentally, this is the same percentage of the population estimated to be intoxicated at any given time.)

However, 42 percent of the American population believes the government routinely hides information from us. This generalized suspicion keeps the Moon hoax idea popping up like a zombie in some cult-classic horror film: You blow its brains out, but the monster just keeps lumbering along.

Fuzzy logic

It doesn't help Moon conspiracy theorists that not one person from the Apollo era's 35,000 NASA employees or 200,000 contractors has ever stepped forward with "whistle-blowing" insider testimony or "smoking-gun" memos about a staged event. Conspiracy theorists also need to explain

IS THIS THE MOON OR NEVADA? The facts clearly show the manned landings on the Moon could not have been faked. Here, lunar module pilot Buzz Aldrin walks on the surface of the Moon near the leg of the lunar module Eagle during the Apollo 11 extravehicular activity. Astronaut Neil Armstrong, commander, took this photograph with a 70mm lunar-surface camera. NASA

eMoon landing?

A PLUME OF FLAME signaled the liftoff of the Apollo 11 Saturn V space vehicle at 9:32 A.M. EDT on July 16, 1969, as astronauts Neil Armstrong, Michael Collins, and Buzz Aldrin headed from Kennedy Space Center Launch Complex 39A to the Moon. NASA

how the Hollywood special-effects wizards who presumably pulled off Academy-Award-winning moonwalk scenes have managed to remain stone silent for decades (despite the fact it would look great on their resumés!). This lack of proof forces conspiracy theorists to counter that the government scared and murdered potential tattletales, including its own astronaut-heroes in a reprehensible assertion that the tragic 1967 Apollo 1 fire was rigged.

A casual browse through Moon conspiracy Internet sites is a mind-numbing journey into the dark side of common sense. The conspiracy theorists are their own worst enemies. They serve up a witch's brew of paranoia, lamebrain science, goofy amateur photo-analysis, and gaping contradictions in logic you could sail the *Titanic* through.

Dark Moon author Mary Bennet purportedly uncovered "secret" documents that show Apollo was a hoax. Bill Brian (*Moongate*) agrees Apollo was a scam but suspects we reached the Moon with the aid of a secret, anti-gravity device that NASA reverse-engineered by copying parts of a captured, alien flying saucer.

Mission implausible

Under cold scrutiny, everyday logic, and low-level science, Apollo conspiracy theories implode faster than a black hole. NASA's own actions are inconsistent with how anyone would attempt to pull off a Moon hoax. If what actually happened during the Apollo program was scripted, the government showed a penchant for gambling and brinkmanship. For example, the government "pretended" to almost kill one of the crews (Apollo 13) to boost television ratings. NASA also had an astronaut "pretend" to break a camera (Apollo 12) after squandering billions of dollars on Hollywood special effects.

The scientific samples, photographic evidence, and telemetry from the Moon are incontrovertible. For this to be otherwise, the world's foremost planetary scientists would have to be dead wrong (imagine the book: *Moon Rock Analysis for Dummies*). Or even more fantastic, scientists have *their own* international conspiracy to pawn off phony data — an idea even more impossible than a government conspiracy.

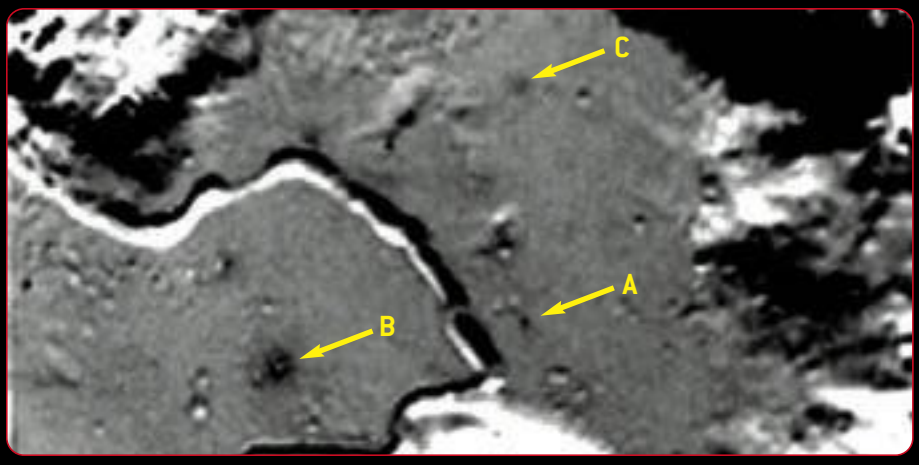
The hours of astronaut moonwalk video are far too complex to have been faked with 1960s motion-picture special-effects technology (unless the Apollo billions were really spent building a time machine to bring back from the future an image-rendering computer and powerful animation software).

Seeing is believing

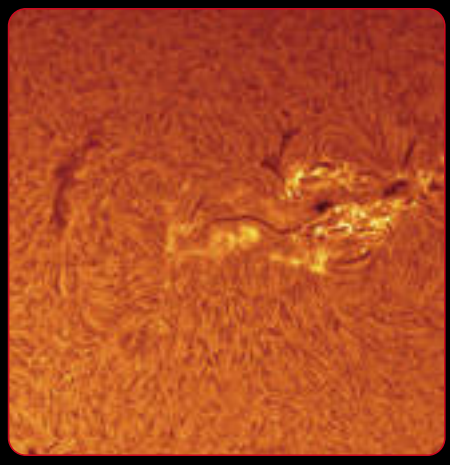
One Moon conspiracy theorist claim is that you can't simply look at the Moon and directly see evidence of human visitation. The six lunar-lander descent stages left on the Moon are small compared to our satellite as a whole — only about 15 feet across. Even the eagle-eyed Hubble Space Telescope can see an object no smaller than 265 feet across at the Moon's distance. However, two researchers, Misha Kreslavsky of Brown University and Yuri Shkuratov of the Kharkov Astronomical Observatory in the Ukraine, recently uncovered the first direct visual evidence of human visitation to the Moon. They had been comparing the 1994 Clementine lunar orbiter images with Apollo images taken more than thirty years ago for evidence of fresh cratering activity. In doing so, they discovered a disturbed regolith (but no impact crater) around the exact location of the Apollo 15 landing site.

Five small, nuclear-powered stations left behind by the astronauts transmitted telemetry information from twenty-five separate experiments, yielding information about the Moon's seismic activity, subsurface temperature, rate of micrometeorite impacts, and other surface properties. In 1977, the experiments were turned off for budgetary reasons. However, the central station transmitters continue to send signals that have been used for spacecraft navigation

Ray Villard *is news director for the Space Telescope Science Institute, an astronomy professor, and a freelance science writer.*



LUNAR ORBITERS HAVE GATHERED RECENT EVIDENCE that we've been to the Moon. This image, taken by the Clementine spacecraft, shows a diffuse dark spot (A) at the exact location of Apollo 15's lunar module, Falcon. Lunar geologists believe the discoloration was caused by the craft's engine blast at takeoff. The other designated areas (B) and (C) are related to fresh impact craters. M. A. KRESLAVSKY AND Y. G. SHKURATOV



SOLAR FLARES are a danger to astronauts in space. This hydrogen-alpha image of the Sun (the bright area to the upper right of the image is a large flare) was taken on June 7, 2003, from Portal, Arizona. JACK NEWTON

checks, gravitational experiments, mapping planetary positions, and precisely measuring Earth's shape. The stations also include a small mirror array called a retroreflector that astronomers have used to bounce laser beams off the Moon for more than thirty years to precisely measure distances to an accuracy of three-quarters of an inch.

Some 842 pounds of Moon rocks — ancient anthracites, lava basalts, and breccias (agglomerations of fractured pieces from meteorite impacts) — have been shared with the worldwide geology community. Radioisotope dating of these samples indicates ages significantly older (4.4 billion years) than the oldest Earth rocks (3.8 billion years), meaning the rocks are very well preserved, partly because they are bone-dry. You simply don't walk down to the beach and pick up a 4.4 billion-year-old rock. Trying to fool the entire geology community is like trying to fool Mother Nature. Where did these rocks come from if not from the Moon's surface?

Fantastic voyage

Fundamental to the conspiracy theory is our supposed inability to go to the Moon. Some scientists were saying the very same thing at the time American pioneer Robert Goddard was launching rockets in a Massachusetts farm field. The thought of humans traveling to the Moon was so fantastic even early science-fiction writers didn't predict it happening for centuries to come.

Going to the Moon certainly was rocket science. But you don't need breakthrough physics or warp-drive to make the trip. The modern rocket engine is based on science principles formulated by Isaac Newton centuries ago. The hardest part of going to the Moon is climbing out of Earth's gravitational field. The immense launch complex at NASA's Kennedy Space Center in Florida and the extraordinary Saturn V rockets that hurled our astronaut pioneers to the Moon were what accomplished this task, and nothing was phony about them. Ask any one of the thousands of media or VIP guests who witnessed the mighty rockets climb majestically on Promethean flames into the topaz Florida skies.

Besides, NASA didn't need such a brawny rocket for a hoax. It could have launched a few small rockets (Saturn 1-B class) and explained it was assembling the Moon ship in low Earth orbit (a strategy considered in the 1960s). Also, hoaxers could have gotten away with a single vehicle. The actual lunar orbit rendezvous approach — requiring a separate orbiter and lander vehicle — was so complex it automatically invited scrutiny by doubters.

To the danger zone

To be sure, space travel is hazardous. One obstacle cited by detractors is the Van Allen radiation belts, which are caused by Earth's magnetic field. Electrons and protons zipping along magnetic field lines can degrade electronics on spacecraft. But rushing toward the Moon at 7 miles (11 km) a second, the Apollo astronauts spent just a few hours within the belts.

The biggest potential threat for space travelers is from solar flares. The radiation from a giant flare is equal to 40 billion atomic bombs exploding at once. Fortunately, this amount of radiation is dispersed widely through space. Also, the Sun was at a minimum in its 11-year cycle of activity during the Apollo years, so deadly flares were rare. A radiation sensor outside the Apollo 12 spacecraft registered one small solar flare, but no increase in radiation dose to the crewmen in the spacecraft was detected.

Another popular Moon conspiracy idea is that micrometeoroids would have sandblasted the spacecraft either in space or on the Moon's surface. This far-out claim has no basis in reality. It's well documented that even when Earth passes through a particularly intense meteoroid shower, nothing happens to spacecraft. The November 1999 Leonid meteor storm, the most intense since the dawn of the space age, dramatized this point. Not one of seven-hundred operational satellites was damaged during the Leonid meteoroid onslaught.

Is it real or computer graphics?

The crux of the conspiracy theory is the allegation that the moonwalks were filmed on a huge movie set. The argument for synthetic images seems very believable when you look at a film like *Red Planet* (2000), which offers convincing panoramas of astronauts trudging across Mars. Today we take all these fantasy scenes for granted thanks to the revolution in computer

graphics and digital-image processing made possible by microcomputers. Now, images can be completely fabricated with precise control of all scene elements: lighting, texture, motion, and choreography.

Cinema special-effects technology of the 1960s was an emerging art and was truly primitive by today's awesome capabilities. No microcomputers, digital-image processing, or 3-D animation software existed. The decade's landmark space film, *2001: A Space Odyssey*, illustrates the pinnacle of special-effects capability in the 1960s. *2001*'s special effects took more than two years to complete, employed an army of technicians and some of the movie industry's top effects-experts, and swallowed a big chunk of the film's $10.5 million budget.

Even by 1977, all the fantastic *Star Wars* scenes were classic studio effects. Making the final film involved the laborious process of optical printing, where separated elements of a scene had to be assembled directly onto motion-picture film by repeated passes of the film through gigantic optical printers. The film pioneered the computer motion-controlled camera — critical for crafting space scenes as good as the Apollo footage.

Quiet on the Moon set

The first images from the 1969 Apollo 11 landing are so fuzzy it seems like almost anything could have been pulled off — except the effects of the Moon's ⅙ gravity on astronaut motion. A cinematically naïve assertion by Moon hoax advocates is that all scenes were filmed in the Nevada desert. To do this, technicians would have needed to block out the sky — an inconceivable task to pull off without the use of a matte box in front of the lens to block some of the camera's view. This would have required that the camera remain stationary.

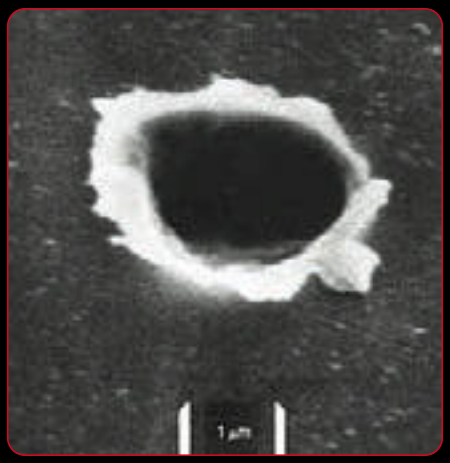
A key problem with a matte box is that shadows would have noticeably changed direction, shifting from west to east as the Sun moved across the sky during the hours of filming. (The Sun moves 15° per hour across Earth's sky, but 13° *per day* across the Moon's.)

Lunar photography 101

A boringly long and trivial list of conspiracy "proofs" exists that argues the moonwalks were artificially lit with classic Hollywood studio lighting. These claims prove only one thing — the conspiracy theorists know less about photography than a high school freshman joining the camera club. Despite truly boneheaded assertions to the contrary, all Apollo images are absolutely accurate and consistent with the reality of a single, really bright light source — the Sun. The only "fill" lighting is from sunlight reflecting off the lunar surface.

Allegations of multiple shadows from multiple lights are red herrings. You can duplicate the Apollo shadows by taking pictures of select foreground and background objects on a sunny day with a $10 camera. The shadows are always parallel but converge toward a point on the horizon as seen in wide-angle lenses.

Topping it off is the highly publicized "gotcha" that there are no stars in the lunar sky. Perhaps the accusers forgot it was daytime on the Moon when pictures were shot. Try photographing stars at midnight with a simple camera pre-set for a sunny day and see what develops. The film used in the primitive Apollo cameras — and even that in the cameras on the space shuttle today — does not approach the dynamic range needed to capture faint starlight



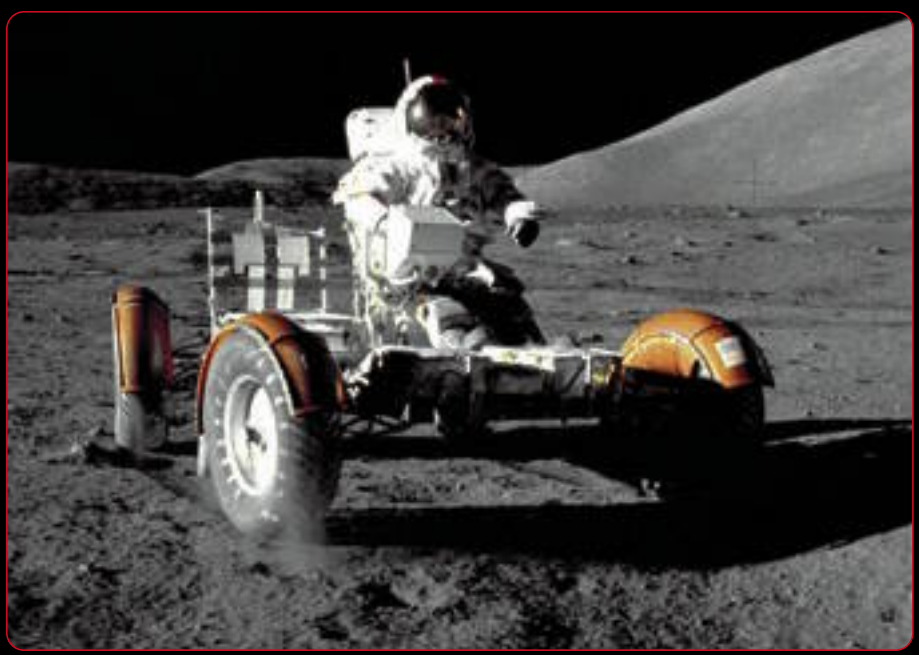
MICROMETEORITES are not a threat to astronauts because impacts from them are rare and the holes they leave are tiny. This micrometeorite impact occurred on one of the metal test-collectors of Skylab, which orbited Earth from 1973 to 1979. NASA

APOLLO 15 BLASTED OFF the lunar surface on its way to rendezvous with the orbiting command module and then back to Earth. Everything about the launch, which was documented on film by a camera aboard the lunar roving vehicle, appeared exactly as it should in ⅙ gravity. NASA

ASTRONAUT ALAN SHEPARD, Apollo 14 commander, stands by the U.S. flag on the Moon's Fra Mauro Highlands. The fact that no stars appear in the sky is a result of the brilliant lunar landscape contrasting with the dark sky. The photographic film used in 1971 did not have sufficient dynamic range to record such differences in brightness. NASA

SHADOWS IN APOLLO IMAGES are consistent with what would be expected on the surface of an airless body at the Moon's distance from the Sun. This Apollo 14 image shows a front view of the lunar module Antares reflecting a circular flare caused by the brilliant Sun. NASA

ASTRONAUT ALAN BEAN, lunar module pilot for Apollo 12, holds a container filled with lunar soil collected during extravehicular activity. The visor reflects no technicians or sound stage equipment, a tough feat to pull off if this picture had been taken in a studio on Earth. NASA



DUST CAPTURED ON FILM behaved exactly as expected in the Moon's reduced gravity. In this photograph, astronaut Eugene Cernan, Apollo 17 mission commander, kicks up a bit of dust while driving the lunar roving vehicle during the early part of the first Apollo 17 extravehicular activity at the Taurus-Littrow landing site. NASA

in a sunlit scene. As in *2001* and other space movies, Hollywood special-effects wizards could have *inserted* stars for artistic effect, but this would have been a dead giveaway the Apollo images were fake.

Mirror on reality

NASA's choice of reflective coatings on helmet visors for the Apollo astronauts also challenges the concept of a fraud. Any catalog photographer will tell you he or she spends hours setting up the lighting to photograph a shiny object like a toaster. The mirrored surface reflects the camera and studio, so a photographer must build a "tent" around the object to reflect the light.

The astronaut helmets were not only reflective gold (for protection against ultraviolet radiation) but also curved, so they acted like wide-angle rear-view mirrors (caution: cinematographer may be closer than he appears). The helmets would have reflected the entire hoax setup: lighting, cameras, and the soundstage technicians. Today, digital trickery allows for realistic reflections to be inserted onto visors. If the Apollo footage really was faked, NASA never would have selected such helmets. In all space movies — including *2001* — astronauts have clear, see-through helmets. NASA could have done the same, and no one would have been any wiser.

Peter Pan on the Moon

I find it amazing that Moon conspiracy theorists obsess over nerdy details about lighting but blithely ignore the precise motion of all objects in the Moon's ⅙-gravity environment. This is the real nail in the coffin against faked Moon videos. Using real actors, it is absolutely impossible to duplicate motion in the absence of gravity or reduced gravity convincingly unless the shot is heavily reprocessed or synthesized digitally.

Conspiracy theorists can't dismiss hours and hours of Apollo footage showing all lunar objects following simple ballistic paths that appeared completely different than they would under the tug of Earth's gravity. This can't be done with slow motion or other conventional film effects. Endless subtleties exist in the Apollo scenes showing the precise, gentle pull of gravity on a true extraterrestrial world: the way dust flew along long, shallow parabolic trajectories when it was kicked up; the trajectories of myriad foil pieces blasted off the lander when the Apollo 16 ascent module lifted off. A final tour de force is footage of the entire Moon rover bouncing along on big arcs.

Curtain call

Thanks to FOX-TV's gambit for ratings, the Moon hoax got some time back in the spotlight, but the effect was minimal. This way-out idea will always hover on the dim periphery of basic common sense, alongside the outrageous collection of other equally absurd "it-never-happened" conspiracy theories.

But the Moon conspiracy folks discredit American heroes, anger a lot of space engineers and scientists, and exasperate NASA spokespersons. The "we-never-went-to-the-Moon" authors come off to the vast majority of the thinking public as nothing more than fools.

For as long as there is a civilization on Earth, the intelligence, boldness, and bravery of the men and women behind the Apollo missions will be remembered. That will never be said for their detractors. All they have managed to do is try and put our national heritage up for sale — and for nothing more than TV ratings.

BY MARTIN RATCLIFFE AND ALISTER LING

JULY 04

Although the bright planets and comets of this past spring have begun to bow out of the way, the overnight and early morning hours start to pick up the slack.

Marvelous night for a moondance

Van Morrison surely wasn't talking about the stark white winter Moon high overhead on a bone-chilling night. The summer Full Moon always rides low all night long, shining with a warm, pale-yellow hue. Why is that? First, consider its phase. For the Moon to appear full, it must lie opposite the Sun in our sky. Imagine talking to a friend at sunset. The only way for his face to be lit completely while looking directly at you is if you stand between him and the Sun with your back to the Sun. You almost could draw a line from the Sun through you to your friend's face. Because the Sun never dips far below the northern horizon in summer, the straight line means that the Full Moon never gets high above the southern horizon.

The Moon's yellow color follows from its staying low in the sky. Moonlight must travel through more air when it lies close to the horizon than when it's high up. The sky-blue color of light scattered by a short column of air is removed from white light traveling through a long path of air, leaving a warmer hue.

Some of the highest tides of the year occur at Full Moon this month. When the closest point of the Moon's orbit (called perigee) falls near the Sun-Earth-Moon line at Full Moon, the lunar and solar tides add together. The next time this happens will be June next year.

THE FULL MOON RISES over Tulsa, Oklahoma, on a late summer's eve. Note how the color changes from orange to near white as its light passes through less of Earth's atmosphere. WILLIAM STERNE

As the brightest twilight colors begin to fade about 50 minutes after sunset, the most prominent object in the western sky is Jupiter. A few months ago, it was a bright, nearly white beacon, but now it appears decidedly weaker and more of a faint peach color. It has faded because Earth has sped to nearly the other side of the Sun, placing Jupiter farther away. As the evening progresses, watch Jupiter's color gradually change toward yellow and then orange as it approaches the horizon, leaving no trace of blue in its light.

The view of Jupiter through a telescope also degrades as the evening progresses. With more air to travel through, its light gets jostled by more turbulence. This is your last chance to see Jupiter close up for a few months. The earlier in the evening you can find it, the better it will appear.

Grab your binoculars for a look at Mars and Mercury paired very close to the horizon as evening twilight begins to fade. Mercury will be easier to find, shining brighter at magnitude –0.2. On July 10, the much fainter Mars lies just 10' (⅓ the apparent diameter of the Moon) below Mercury. Can you spy Mars without a telescope?

The crescent Moon returns to the evening sky after midmonth, floating above Mercury on the 19th and accompanying Jupiter on the 20th and 21st. European observers will see a real close pairing on the 21st.

Venus blazes in all its glory as the morning star. It climbs higher with each passing day and reaches greatest brilliancy (magnitude –4.5) on July 14/15. Venus will herald the dawn and the end to an all-night observing session.

Comet C/2001 Q4 (NEAT) has been putting on a lovely show in the evening sky. The fuzzy snowball still may be visible to the naked eye from a dark location far from city lights. Just aim your binoculars at the pointer stars of the Big Dipper's bowl, and you'll see it. A second comet, C/2003 K4 (LINEAR), floats not far away in northern Boötes.

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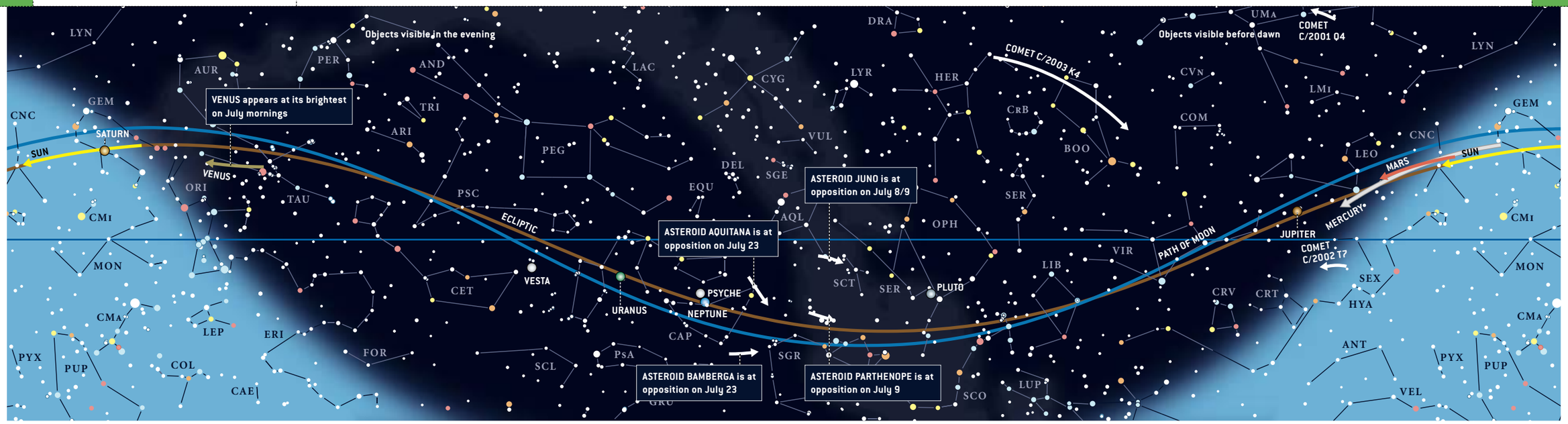
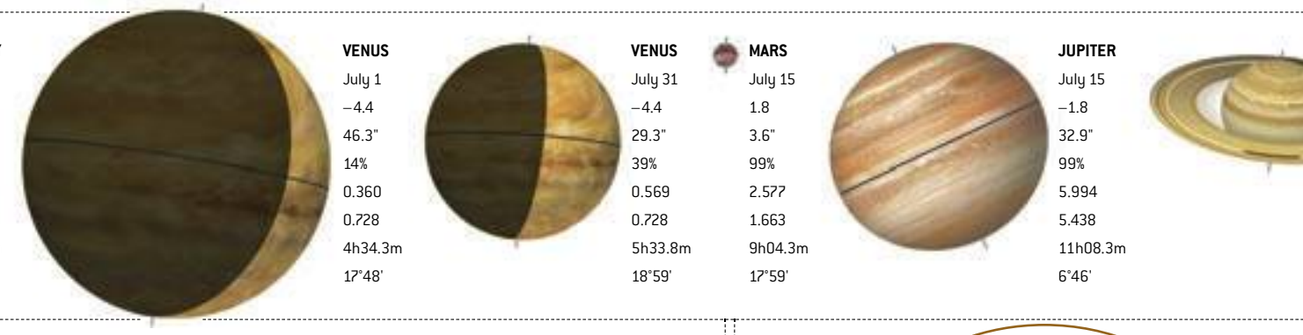
Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



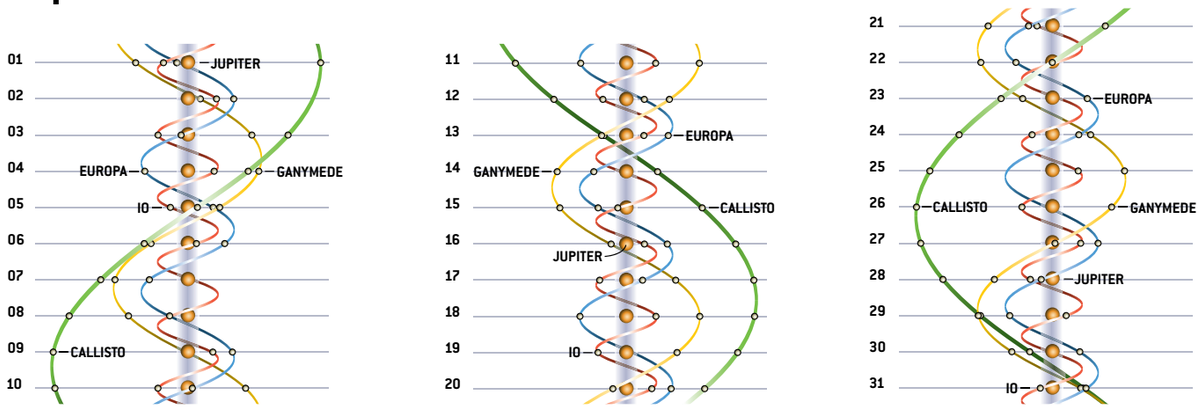
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	July 1	July 31	July 1	July 31	July 15	July 15	July 31	July 15	July 15	July 15
Magnitude	−0.9	0.6	−4.4	−4.4	1.8	−1.8	0.1	5.8	7.8	13.8
Angular Size	5.4"	8.3"	46.3"	29.3"	3.6"	32.9"	16.6"	3.7"	2.3"	0.1"
Illumination	86%	40%	14%	39%	99%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.247	0.810	0.360	0.569	2.577	5.994	10.002	19.300	29.123	29.970
Distance (AU) from Sun	0.356	0.467	0.728	0.728	1.663	5.438	9.044	20.049	30.070	30.820
Right Ascension (2000.0)	7h41.6m	10h23.6m	4h34.3m	5h33.8m	9h04.3m	11h08.3m	7h24.9m	22h33.4m	21h08.0m	17h19.3m
Declination (2000.0)	23°19'	7°58'	17°48'	18°59'	17°59'	6°46'	21°46'	−9°57'	−16°32'	−14°16'



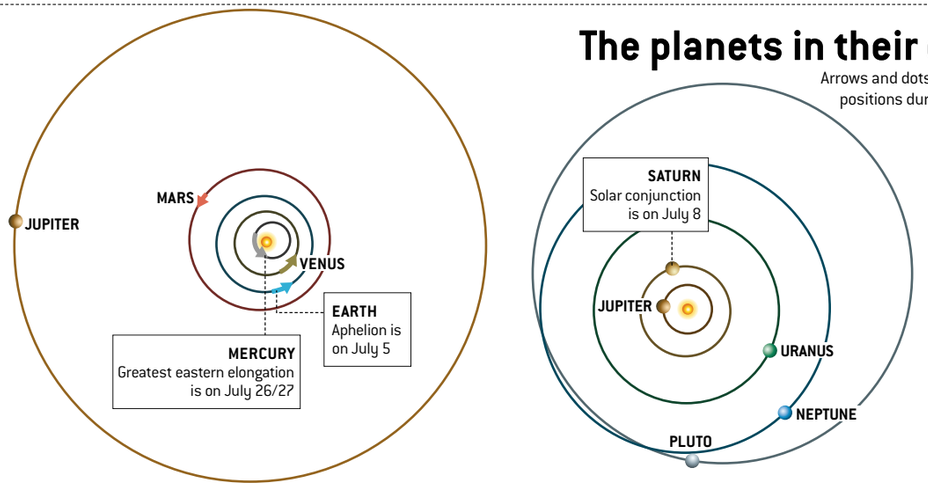
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view in a telescope.



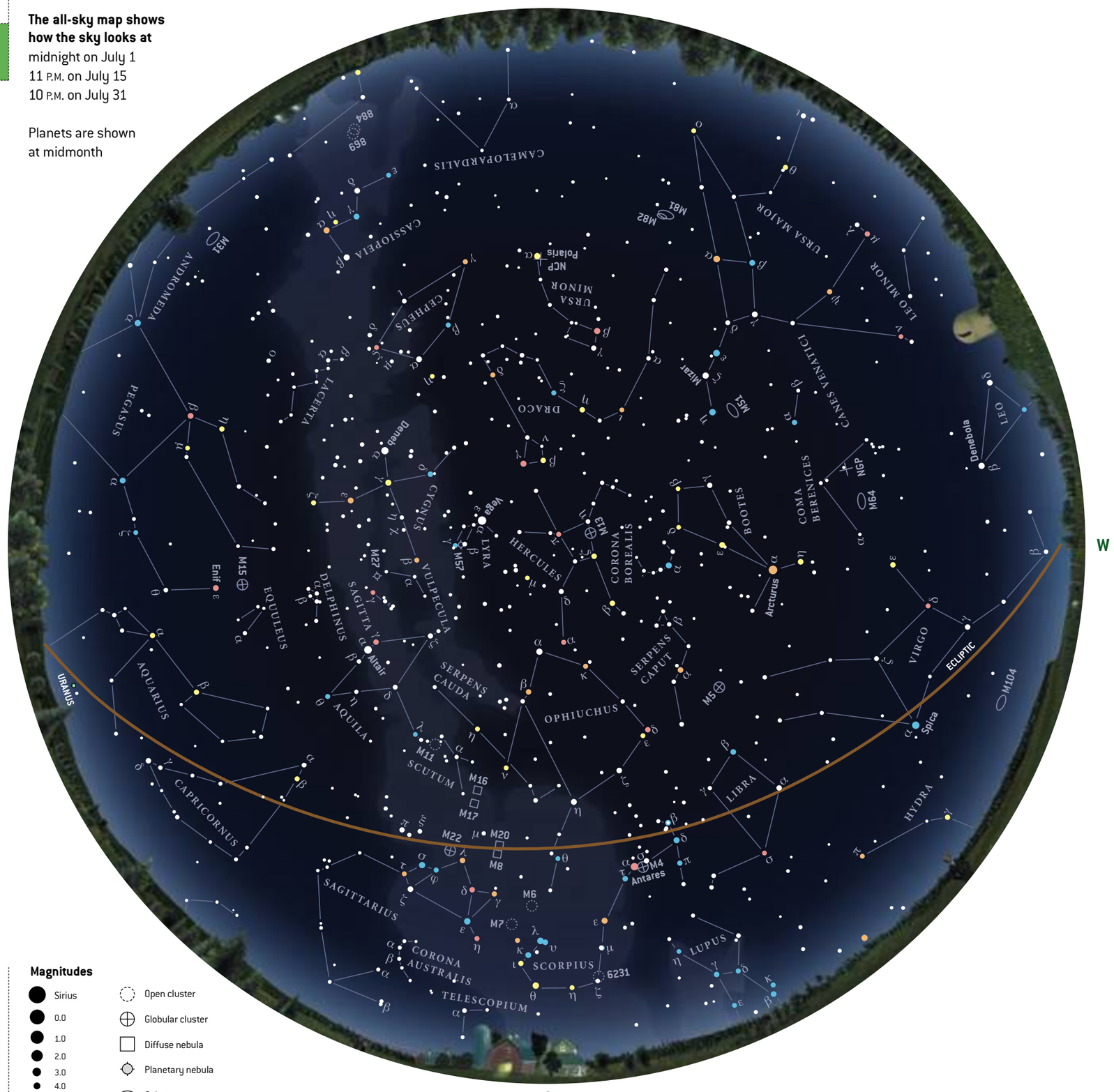
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
midnight on July 1
11 P.M. on July 15
10 P.M. on July 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

july 04

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				[01]	[02]	[03]
[04]	[05]	[06]	[07]	[08]	[09]	[10]
[11]	[12]	[13]	[14]	[15]	[16]	[17]
[18]	[19]	[20]	[21]	[22]	[23]	[24]
[25]	[26]	[27]	[28]	[29]	[30]	[31]

01 The Moon is at perigee (222,108 miles from Earth), 6:57 P.M. EDT

02 Full Moon is at 7:09 A.M. EDT

04 Venus passes 1.1° north of Aldebaran, 6 A.M. EDT

05 Earth is at aphelion (94.5 million miles from the Sun), 7 A.M. EDT

08 Saturn is in conjunction with the Sun, 1 P.M. EDT

Asteroid Juno is at opposition, midnight EDT

09 Last Quarter Moon is at 3:34 A.M. EDT

Asteroid Parthenope is at opposition, 10 A.M. EDT

10 Mercury passes 0.2° north of Mars, 7 P.M. EDT

13 The Moon passes 8° north of Venus, 8 P.M. EDT

14 The Moon is at apogee (252,396 miles from Earth), 5:08 P.M. EDT

Venus is at greatest brilliancy (magnitude –4.5), 9 P.M. EDT

17 New Moon is at 7:24 A.M. EDT

18 The Moon passes 4° north of Mars, 10 P.M. EDT

21 The Moon passes 3° north of Jupiter, 9 A.M. EDT

24 First Quarter Moon is at 11:37 P.M. EDT

26 Mercury is at greatest eastern elongation (27°), 11 P.M. EDT

28 Southern Delta Aquarid meteor shower peaks

30 The Moon is at perigee (223,895 miles from Earth), 2:21 A.M. EDT

31 Full Moon is at 2:05 P.M. EDT

For a definition of terms, visit www.astronomy.com/glossary

To design the perfect telescope family for the beginner or advanced user, you have to think BIG.

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C8-S/C8-SGT/C9¼-S/C9¼-SGT NOW AVAILABLE WITH OPTIONAL

StarBright® XLT HIGH PERFORMANCE OPTICAL SYSTEM

8" Advanced Series Schmidt-Cassegrain Products.....$125

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The new Advanced Series and Advanced Series **Computerized GoTo** telescopes have been designed to offer the novice or more advanced user a selection of models with the **features, quality** and **value** that serious amateurs can appreciate. These scopes come on **NEW heavy-duty German Equatorial mounts** with **NEW ultra-sturdy 2" stainless steel legs** and center brace and accessory tray for superior stability, rigidity and vibration dampening. The Advanced Series comes in a choice of refractor, reflector and Schmidt- Cassegrain models. The refractor models range from a 4" to an impressive 6" aperture. For even more light gathering power there are 6", 8" and a **NEW 10" Newtonian** reflector. There are also 5", 8" and 9 1/4" Schmidt-Cassegrain optical designs that feature Celestron's **precision matched and hand-figured optical systems.**

Auxiliary ports for Hand Control, Dec Motor and AutoGuider.

CG-5 Mount — Precision engineered for stability.

Our **new CG-5 German Equatorial Mount** has precision worm gears on both axes for extremely smooth tracking and slewing. The CG-5 uses large shaft and bearings and substantial base castings for additional stability. The key element that makes this system the most stable in its class is the **NEW heavy-duty tripod** with **larger and more substantial legs** that provide excellent damping characteristics for more stable views. The CG-5 also has a convenient **latitude scale** for easier alignment and an **optional polar finder scope** for the ultimate in precision alignments.

Additional Specifications — Computerized Models

Hand Control	Double line, 16 character Crystal Display; 19 fiber optic backlit LED buttons
Motor: Type	DC Servo motors with encoders, both axes
Max Slew Speed	4°/second
Software Precision	24bit, 0.08 arcsec calculation
Hand Control Ports	RS-232 communication port on hand control
Motor Ports	Aux Port, Autoguide Ports
Tracking Rates	Sidereal, Solar and Lunar
Tracking Modes	EQ North & EQ South
Alignment Procedures	AutoAlign, 2-Star Alignment, Quick Align
Database	40,000+ objects, 400 user defined programmable objects

GoTo convenience and GPS compatibility for precision accuracy.

We are proud to offer the GT versions of the Advanced Series on a computerized **GoTo** version of Celestron's sturdy CG-5 mount. Couple this solid mount with the included **NexStar® computer control system** and utilize many of the same features as Celestron's most advanced GoTo telescopes like an **Autoguider port** for long exposure deep sky astro-photography. **GoTo models are also upgradeable to GPS** with the optional **CN16 GPS Accessory (#93963).** It allows your telescope to pinpoint your position on the Earth, the date and time, and makes the alignment process faster and easier than ever before!

C9¼-SGT (#11046)

C10-NGT (#11048)

These GoTo versions of the Advanced Series also come loaded with new software features and **over 40,000 database objects**. Capable of holding over 35 lbs of payload and slewing at 4° per second, you will be able to instantly point to any of the celestial objects in the database.

NEW 2003 PRODUCT GUIDE

To request a copy of our new 2003 Product Guide, contact us at (310) 328-9560.

Specifications — All Advanced Series Telescopes

	21036 C4-R	11071/11072 C5-S	31056 C8-N	21019/21020 C6-R	11025/11024 C8-S	31061/31062 C8-N	11045/11046 C9 1/4-S	11043/11048 C10-N
Optical Design	102mm (4.0") refractor	127mm(5") Schmidt-Cassegrain	150mm (6.0") reflector	150mm (6.0") refractor	203mm (8") Schmidt-Cassegrain	200mm (8.0") reflector	235mm (9.25") Schmidt-Cassegrain	254mm (10") reflector
Focal Length	1000mm f/10	1250mm f/10	750mm f/5	1200mm f/8	2032mm f/10	1000mm f/5	2350mm f/10	1200mm f/4.7
Finderscope	6x30	6x30	6x30	9x50	6x30	9x50	6x30	9x50
Mount	CG-4 Equatorial	CG-5 Equatorial	CG-4 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial
Eyepiece	1-1/4" – 20mm (50x)	1-1/4" – 25mm (50x)	1-1/4" – 20mm (38x)	1-1/4" – 20mm (60x)	1-1/4" – 25mm (81x)	1-1/4" – 25mm (50x)	1-1/4" – 25mm (94x)	1-1/4" – 20mm (60x)
Star Diagonal	1-1/4"	1-1/4"	n/a	1-1/4"	1-1/4"	n/a	1-1/4"	n/a
Accessory tray	yes	yes	yes	yes	yes	yes	yes	yes
Tripod	Aluminum	2" Stainless Steel	Aluminum	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel
CG mount	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky LT

PRICING*: C10-NGT (#11048): $1,149 + $95 S&H; C10-N (#11047):$849 + $75 S&H; C9¼-SGT (#11046): $1,699 + $105 S&H; C9¼-S (#11045): $1,399 + $85 S&H; C8-SGT (#11026): $1,299 + $75 S&H; C8-S (#11025): $999 + $85 S&H; C8-NGT (#31062): $949 + $85 S&H; C8-N (#31061): $649 + $65 S&H; C6-RGT (#21020): $999 + $95 S&H; C6-R (#21019): $799 + $75 S&H; C6-N (#31056) $399 +$50 S&H; C5-SGT (#11072): $1,099 + $75 S&H; C5-S (#11071): $849 + $65 S&H; C4-R (#21016): $399 + $40 S&H

*Prices shown are U.S. mail order.

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OMNI® Eyepieces — 1¼"

- **4-element premium symmetrical optical design**
- Fully multi-coated
- 52° (43° for 40mm) field of view
- 2-step anodize process to prevent reflection from top surfaces
- Blackened lens edges

#93316 - 4mm $44.00
#93317 - 6mm $44.00
#93318 - 9mm $44.00
#93319 - 12.5mm $44.00
#93320 - 15mm $44.00
#93321 - 20mm $44.00
#93322 - 25mm $44.00
#93323 - 32mm $54.00
#93325 - 40mm $54.00

OMNI® Barlow Lens — 1¼"

- 2x
- Fully multi-coated
- Short tube design

#93326 - 1-1/4"OMNI Barlow $49.00

E-Lux® Eyepieces 2"

- 3-element optical design
- **Fully multi-coated**
- Field of View – 56° (26mm and 32mm), 50° (40mm)
- 22mm Eye Relief

#93334 - 26mm $69.00
#93335 - 32mm $69.00
#93336 - 40mm $79.00

E-Lux® Eyepieces —1¼"

- Traditional Plössl optical design
- Fully-coated

#93300 - 6mm $34.00
#93301 - 10mm $34.00
#93302 - 25mm $34.00
#93303 - 40mm $34.00

Ultima® Eyepieces —1¼"

- **5-element hybrid optical design**
- Fully multi-coated
- Blackened lens edges

#93350 - 5mm .....$ 79.00
#93351 - 7.5mm .....$ 79.00
#93348 - 10mm .....$ 79.00
#93352 - 12.5mm .....$ 79.00
#93353 - 18mm .....$ 79.00
#93349 - 30mm .....$ 99.00
#93355 - 35mm $109.00
#93356 - 42mm .....$ 99.00

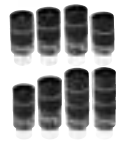
Power Tank 17

NEW!

- Take your telescope anywhere with this portable rechargeable power supply
- 17 amp hour, 12 Volt D.C.
- 2 x 12V DC output car jack socket
- DC 3, 6, 9V output jacks
- Built-in AM/FM Radio and Siren
- Removable red filtered flashlight with magnetic back
- Multi-angle 800,000cp emergency Halogen spotlight
- Jump-start system - 250 cranking AMPS (5 sec.)
- Built-in circuit breaker for safety
- Cigarette lighter adapter included
- Switchable 110v-220v AC adapter

#18777 - Power Tank 17 .....$129.00

X-Cel® Eyepieces — 1¼"



- **6-element optical design utilizing ED glass**
- Fully Multi-coated. All air-to-glass surfaces have 5 layer multi-coating
- Field of view 55°
- Parfocal – little to no focusing adjustments are needed when switching from a low power to high power eyepiece
- 20mm eye relief and soft rubber roll down eyecups
- More than 25mm of clear aperture even on the high powers for comfortable high power viewing
- Each eyepiece comes with a durable plastic case

#93386 - 2.3mm $69.00
#93387 - 5mm $69.00
#93388 - 8mm $69.00
#93389 - 10mm $69.00
#93390 - 12.5mm $69.00
#93391 - 18mm $69.00
#93392 - 21mm $69.00
#93393 - 25mm $69.00

Axiom® Eyepieces — 1¼", 2"

- **7-element optical design**
- **70° EXTRA WIDE** field of view (except 50mm)
- Fully multi-coated

1-1/4"
#93357 - 15mm $139.00
#93358 - 19mm $149.00
#93359 - 23mm $179.00

2"
#93362 - 19mm $189.00
#93363 - 34mm $239.00
#93364 - 40mm $289.00
#93365 - 50mm $329.00

10mm Plössl Reticle Eyepiece —1¼"

- Five-element guiding eyepiece
- Reticle pattern is a .0075" double spaced line system
- Multi-coated optics for increased contrast
- Long eye relief
- High power is ideal for guiding
- 50° apparent field of view
- Optional illuminator is required ($39)

#94169 10mm Plössl Reticle Eyepiece —1-1/4" $124.00

Power Tank™

- 12-volt rechargeable power supply
- 7-amp hour
- Two 12V output cigarette lighter ports
- 3V, 6V and 9V outputs for accessories
- Built-in flashlight with red filter cap
- 800,000 candle power halogen emergency spotlight
- Booster terminal on rear side
- Built-in circuit breaker for safety
- Cigarette lighter adapter included
- AC adapter included (120V-220V)

#18774 - Power Tank. $69.00

Filter & Eyepiece Kit

- Five Superior Grade Plössl Eyepieces — 1.25"; Barlow Lens — 2x 1.25"
- Six Colored Eyepiece (Planetary) Filters; Moon Filter — 1.25"
- Aluminum Carrying Case

#94303 - Filter & Eyepiece Kit $149.00

Ultima® 2x Barlow —1¼"

- **Three-element apochromatic design**
- 27mm clear aperture
- Fully multi-coated

#93506 - 1-1/4"Ultima Barlow $79.00

Microguide Eyepiece —1¼"

- Laser-etched reticle with built-in, battery illuminator
- Multi-coated 12.5mm Abbe (4-element) Orthoscopic
- Direct guiding on stars outside the center of the field of view
- Greatly improved off-axis guiding to capture much fainter, sharply focused guide stars without reducing limiting magnitude
- Measure position angles and separation of double stars

#94171 - Microguide Eyepiece 1-1/4" $194.00

Erect Image Diagonal —1¼"-90°

- Amici prism design allows you to view sky objects at a comfortable 90° and view land objects oriented properly, meaning the image is upright and correct from left to right.

#94108 - Erect Image Diagonal —1-1/4"-90° $39.00

Erect Image Diagonal —NX4

- Amici prism design allows you to look into your NexStar 4 at a 45° angle, and view land objects oriented properly, meaning the image is upright and correct from left to right.

#94116 - Erect Image Diagonal —NX4 .....$29.00

Radial Guider

- Use with Schmidt-Cassegrain telescopes in prime focus, deep-sky imaging or astrophotography
- Simultaneously photograph and guide through the optical tube assembly of the telescope
- Adjustable prism and rotating eyepiece collar give wider section of sky for finding a guide star
- Eliminates the problem of differential flexure

#94176 - Radial Guider $124.00

Reducer/Corrector

- Works with all Celestron C5, C8, C9-1/4 , C11 and C14 telescopes
- Minimizes coma and flattens field of view for pinpoint off-axis stars
- Reduces exposure times by 60% and increases field of view
- f/6.3 for C5, C8, C91/4 and C11 telescopes and f/7 for the C14 telescope

#94175 - Reducer/Corrector $139.00

2" Mirror Diagonal

- 2" 90° Mirror Diagonal to thread on Schmidt-Cassegrain telescopes
- Includes an adapter to use with refractor telescopes
- Includes an adapter to accept 1-1/4" eyepieces
- Multi-coated mirror
- Smooth mechanics that are precision manufactured for reliability

#93519 - 2" Mirror Diagonal $89.00

Exotherm Reusable Hand Warmer

NEW!

- Perfect for chilly evenings outdoors, camping, stargazing, or at sporting events
- Convenient, reusable, and made from nontoxic materials
- Heat lasts up to 1 hour

93504 - Exotherm Reusable Hand Warmer $10.00

NEW!

GPS Accessory CN16

- Use the power and accuracy of GPS satellites to align your telescope with the optional CN-16 GPS Accessory. Plug the GPS receiver module into your telescope to link up and automatically download information from one of many global positioning satellites
- Kits include CN16 and installation components

#93966 - CN-16 kit for Advanced GT $269.00
#93963 - CN-16 kit for NexStar "i" Series $229.00
#93967 - CN-16 kit for CGE Series $249.00

Vibration Suppression Pads

- Reduces vibration time by almost 100% and decreases vibration amplitude
- The pads fit between the bottom of the tripod legs and the ground

#93503 - Vibration Suppression Pads (3) $59.00

Contrast - Booster Filter —1¼"

by Baader

- Eliminates color aberration inherent inachromatic refractor telescopes
- Eliminates the blue hue around lunar and planetary subjects
- Multi-layer coatings for 95% transmission

#94121 - 1-1/4" Contrast-Booster Filter $49.00

Model A — for 1-1/4" eyepieces

Model B — for back threads of SC's

LPR (Light Pollution Reduction) Filters

- Made of high quality, flat polished optical glass
- Over 40 layers of coating
- Broadband anti-reflection coating prevents ghosting and improves contrast

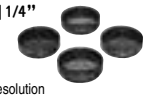
#94126A - LPR Filter Model A—1-1/4" $69.00
#94127A - LPR Filter Model B $99.00

1¼" Polarizing Filter Set

- Transmits only light moving along a specific plane; increases contrast between surfaces with different planar transmissions
- Polarization effect makes blue skies a deeper blue, eliminates surface reflections and helps reduce atmospheric haze

#93608 - 1-1/4" Polarizing Filter Set $29.00

Eyepiece Filter Sets —1¼"



- An invaluable aid in planetary and lunar observing
- Reduces glare and light scattering
- Increase contrast, definition and resolution
- Lessens eye fatigue

#94119-10 (21, 80A, 15, Polarizing) $44.00
#94119-20 (12, 25, 56, ND-25) $44.00
#94119-30 (23A, 38A, 58, ND-50) $44.00
#94119-40 (8, ND-13, 47, 82A) $44.00

Night Vision Flashlight

- Two red LEDs
- Adjustable brightness
- Uses a single 9V battery (included)

#93588 - Night Vision Flashlight $19.00

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THE DEEP SKY

Comet C/2001 Q4 (NEAT) draws our attention to the inhabitants of deep space that lurk in and near the bowl of Ursa Major's Big Dipper asterism.

Call to order

Everyone knows what the Big Dipper looks like, so it will be easy to answer the question: "Where is Comet C/2001 Q4 (NEAT)?" The two pointer stars at the end of the bowl, Alpha (α) and Beta (β) Ursae Majoris, lie less than one binocular field from Q4 all month. And on the 20th, the comet lies right between them.

The bright stars in most constellations are assigned a letter of the Greek alphabet, Alpha for the brightest, Beta for the second brightest, and so on. Ursa Major is one of the few exceptions to this rule. The seven bright stars that make up the Big Dipper asterism are ordered from end to end, starting at the star closest to Polaris, the North Star.

Take a second look at Alpha. Not all stars have the same color: This one appears distinctly yellow compared with its whiter neighbor, Beta. A star's color directly reflects its surface temperature. The cooler a star, the redder it appears; hotter stars glow more blue-white. Our Sun's color (and surface temperature) lies almost smack between that of Alpha and Beta UMa. Temperature isn't everything, however — Alpha is much bigger than our Sun, so even though Alpha is cooler, it emits more than one hundred times the energy. If you could place our Sun at Alpha's distance, it would just be visible to the naked eye on a good, dark night.

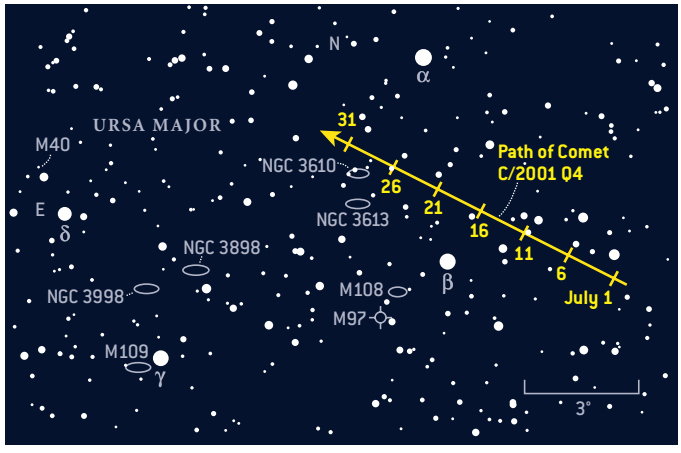
In his *Catalogue of Nebulae and Star Clusters*, the 18th-century French comet hunter Charles Messier identified and described a number of non-stellar objects. In the late 1700s, the optical quality of most telescopes was poor compared with what's available today. The somewhat blurred image of a close stellar pair was difficult to distinguish in those scopes and could mislead the unwary into thinking they had found a comet or nebula. Messier, however, could see them for what they were.

Messier included one such pair in his catalog, M40 in Ursa Major. It consists of a 9.6- and 10.1-magnitude star an easy 52" apart. This gap — large enough to contain the disk of Jupiter — testifies to the low quality of an "ordinary" telescope in those days. Modern scopes have no problem at all separating the two stars. No other double stars made Messier's catalog.

Galaxies galore

Ursa Major is so big and full of galaxies, it's hard to know where to start observing. A different sort of observing project is to see how deep you can go within a limited area, such as the bowl of the Big Dipper. Start with the four galaxies brighter than 11th magnitude: NGC 3610, NGC 3613, NGC 3898, and NGC 3998. After you spot these, jump back to the brighter Messier galaxies M108 and M109 just outside the bowl. Suddenly, it seems they have much more detail than before. Observing fainter objects helps train your eye to see detail in all objects.

During your next observing session, raise the bar to 12th magnitude for another eight galaxies. You'll need to bring a more detailed chart. How deep can you go?



SPIRAL GALAXY NGC 3898 resides in the bowl of the Big Dipper, where this month it greets Comet C/2001 Q4. DPOSS

Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

THE PLANETS

As the evening sky loses its monopoly on planets, the late-night sky offers two distant gas giants near their peak, and the morning sky blazes with Venus.

Jupiter, Mars, and Mercury make brief appearances during summer evenings, while Venus and Saturn gleam in the morning sky. Although the bright planets no longer dominate the late-night sky, giant planets do. Uranus and Neptune, each five times the diameter of Earth, are easy targets with binoculars — the challenge is to identify them correctly.

Jupiter lies low in the western evening sky, setting about three hours after the Sun in mid-July. The planet shines at magnitude –1.8 and easily pierces the early evening twilight. As the sky darkens, look for Regulus, the brightest star in Leo the Lion, lying to the lower right of Jupiter.

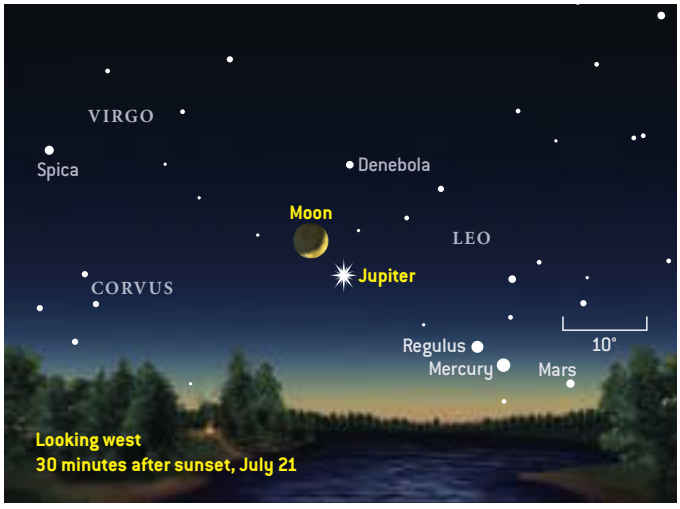
If you use a telescope, catch Jupiter early in the evening because details in its atmosphere become harder to see as the planet sinks toward the horizon, and turbulence in Earth's atmosphere increases. Viewing the planet in twilight has its rewards because the planet's glare is reduced. July offers a final chance to witness some of the Callisto satellite events listed on page 66. This series of eclipses and occultations ends in September, when Jupiter is in conjunction with the Sun and hence invisible from Earth.

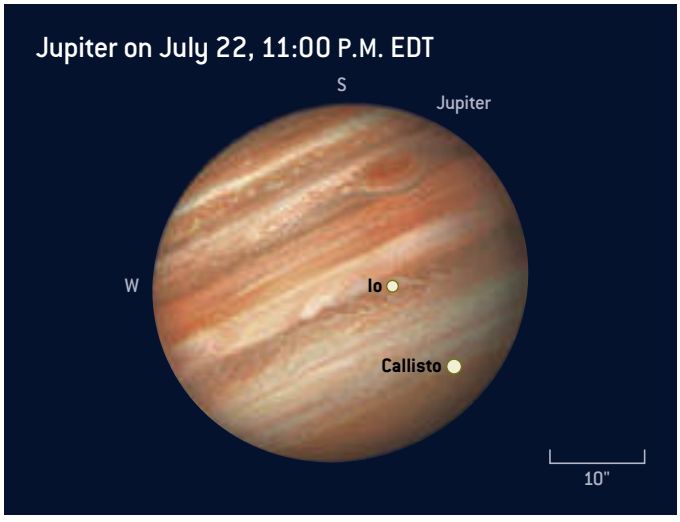
Watch for the attractive pairing of the waxing crescent Moon and Jupiter on July 20 and 21. On the first of these nights, Jupiter stands 8° to the Moon's left. The following night, Jupiter lies approximately 5° to the lower right of the Moon.

This is also a good time to look for the brief appearance of **Mercury**. This doesn't rank among the best of the year's opportunities to view Mercury because the planet never rises far above the western horizon. Consequently, you'll need clear skies and an unobstructed horizon toward the west to spot it. On July 1, Mercury lies 5° south of Pollux in Gemini and shines at magnitude –0.8. Mercury fades slowly throughout the month, making it more difficult to see in the bright twilight. On the 8th, it passes through the middle of the Beehive star cluster (M44), although the pair lies only 20° from the Sun.

Mars lies 1.9° west of Mercury on this night, although you'll need a telescope to see it. Mars shines at magnitude 1.8, about seven times fainter than Mercury, and will be even harder to pull out of the twilight. Two nights later, Mercury lies within the same telescopic field of view, with just 10' separating the planets. Mercury then shines much brighter, at magnitude –0.2.

On July 19, Mercury lies 5° below a slender crescent Moon. On the following evening, with the Moon near Jupiter, Regulus appears nearly 10° to the lower right of the Moon and Mercury stands 5° farther down in the sky. On the 25th, Mercury joins Regulus with only three





Moon widths (1.5°) separating them. On that evening, Jupiter stands to the pair's far upper left and Mercury sets around 9 P.M. local daylight time. Mercury quickly sinks out of sight as it heads to a more southerly declination. Its greatest elongation occurs on July 26/27, when it lies 27° east of the Sun.

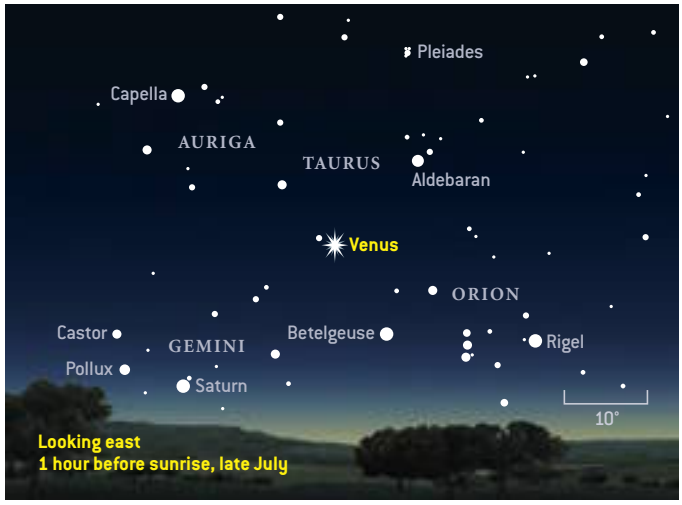
Later on July evenings, **Neptune** pokes above the eastern horizon, appearing in the southeast after 10 P.M. local daylight time. You can find the 7.8-magnitude planet wandering north of Theta (θ) Capricorni. July opens with Neptune positioned 1° northeast of Theta and 10' north of a 6.9-magnitude star. By the 31st, Neptune has moved westward to lie exactly 0.5° north of Theta. Tripod-mounted

binoculars will let you pick out Neptune without any difficulty.

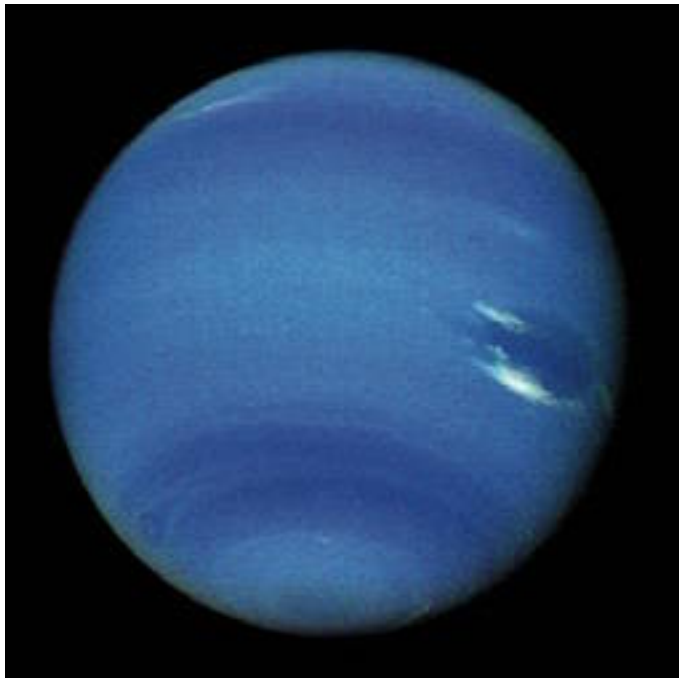
Uranus rises an hour after Neptune. It lies in the south-central part of Aquarius in a rather empty area of the south-eastern sky. The star nearest to its location is 4.8-magnitude Sigma (σ) Aquarii. Sigma lies 10° due south of Zeta (ζ) Aquarii, the central star of the familiar triangle formed by Gamma (γ), Eta (η), and Pi (π) Aquarii. On July 1, you can find Uranus 1.3° northeast of Sigma, well within the same binocular field. Throughout July, Uranus moves closer to Sigma, ending the month 0.6° north of the star. Uranus glows about one magnitude dimmer than Sigma.

Brilliant **Venus** rises as dawn breaks on July 1, standing a scant 1.3° north of Aldebaran, the brightest star in Taurus the Bull. During July, Venus treks across the entire constellation of Taurus, ending the month just 3° south of the Crab Nebula supernova remnant (M1). Through a telescope, Venus displays an elegantly thin crescent, just 14 percent illuminated and a giant 46" from tip to tip on the 1st. It reaches greatest brilliancy on July 14/15, shining then at magnitude –4.5.

As the planet continues to move away from the Sun, which it transited last month, the phase increases until it reaches 39 percent on July 31. By this time, Venus rises at 3 A.M. local daylight time. Because the planet orbits the Sun faster than we do, it moves away from us. This results in a shrinking disk size, reaching 29" across by month's end. Look for the crescent Moon above Venus on the morning of July 13. The following morning, the waning Moon lies 10° to the left of Venus.



Saturn reaches solar conjunction on July 8, and by the end of the month the planet reappears from behind the Sun. On the 31st, the ringed planet rises around 4 A.M. local daylight time and shines at magnitude 0.1. Pollux, the brightest star in Gemini the Twins, stands nearly 8° to the left of Saturn. If all has gone well, the Cassini spacecraft now should be orbiting the planet following its July 1 orbit insertion burn. The spacecraft is destined to change forever our perspective of this beautiful ringed world.



GAS GIANT PLANETS Uranus (left) and Neptune rise during late evening, making tempting targets for observers with binoculars or a telescope. NASA/JPL

METEORS AND MOONS

This is the last month to view eclipses, occultations, and transits of Jupiter's outer moon Callisto. Closer to home, Earth's Moon displays an intriguing crater for Full Moon observers.

Streaks from Aquarius

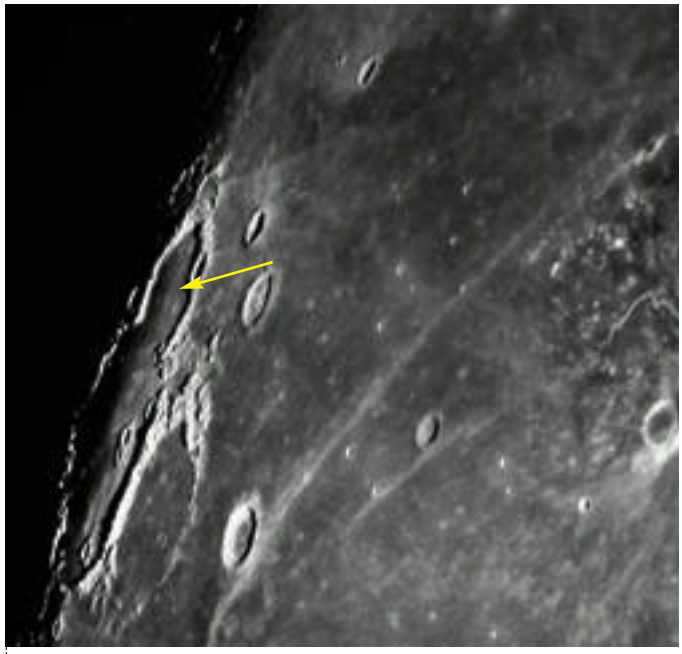
The bad news: A bright Moon adversely affects all the late July meteor showers, including the leading edge of the Perseid shower that peaks next month. The good news: This means the Moon will be absent for the Perseid peak in mid-August.

Three separate streams of meteors appear from the general area of Aquarius in late July: the Delta Aquarids, which are separated into a northern and southern stream, and the Iota Aquarids. Easily the largest of these showers is the southern Delta Aquarids, which usually is active during the final two weeks of July. The Iota Aquarid shower begins ramping up during the final week of the month. The Full Moon on July 31 all but blots out these showers, except for the rare fireball.

Moon feature: Russell

The western limb of the Moon is home to an unusual crater that honors two individuals. Russell pays tribute to both John Russell, a British painter, amateur astronomer, and selenographer, and American astronomer Henry Norris Russell. Russell the crater is a 62-mile-wide (99 km) walled plain located on the western edge of Oceanus Procellarum. A few small craters dot the floor of Russell. This region comes into sunlight just a day before Full Moon, so look for it toward the end of July. The northern, eastern, and western walls of Russell are complete, but the southern wall is missing. The area where you would expect to see the southern wall instead opens up into an even larger walled plain called Struve. On older maps, Russell is called Struve A.

The 14-mile-wide (23 km) crater Briggs A intrudes on the eastern wall of Russell. Lots of detail peppers the western wall, including some clefts and a small crater. The northern wall is very complex geologically, overlapping what looks like an ancient crater. Notice the two rays that emanate from this region across the mare to the east. Also to the east of Russell lie two craters called Briggs and Briggs B.



THE CRATER RUSSELL (arrow), which lurks near the Moon's western limb, has no southern wall but complex borders on the other three sides. FROM *THE CONSOLIDATED LUNAR ATLAS* (LPL/UA)

CALLISTO'S DISK transited Jupiter on January 18, 2003. The disk appears second from the right, to the left of Io's shadow and to the right of Io's disk. July offers the last observable Callisto events for several years. DAMIAN PEACH

Jupiter's satellites

This will be your last chance to view the rare occultations, eclipses, and transits involving the outer Galilean moon, Callisto. During each 12-year orbit of Jupiter around the Sun, only two such series occur. The current one began in late 2001 and continues until September 20, 2004, but none will be visible after July because of Jupiter's impending conjunction with the Sun. The events listed in the table above are given in 24-hour format in both Universal Time and Eastern Daylight Time. Tr = transit; I = Ingress; E = Egress; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance. The events are worth viewing due to their rarity. Not all events are visible from the United States.

/// JULY CALLISTO EVENTS

	{ UT }	{ EDT }	{ Event }
6th	6h29m	2:29	IV.Tr.I.
	10h02m	6:02	IV.Tr.E.
	17h18m	13:18	IV.Sh.I.
	19h36m	15:36	IV.Sh.E.
14th	15h53m	11:53	IV.Oc.D.
	19h25m	15:25	IV.Oc.R.
		22:17	IV.Ec.D.*
15th	2h17m		IV.Ec.D.*
	4h26m	0:26	IV.Ec.R
22nd		22:11	IV.Tr.I*
23rd	2h11m		IV.Tr.I.*
	5h35m	1:35	IV.Tr.E.
	11h22m	7:22	IV.Sh.I.
	13h26m	9:26	IV.Sh.E
31st	11h55m	7:55	IV.Oc.D.
	15h16m	11:16	IV.Oc.R.
	20h25m	16:25	IV.Ec.D.
	22h18m	18:18	IV.Ec.R.

*Events that occur on either side of midnight are shown twice.

COMETS AND ASTEROIDS

Although the best comet viewing season in seven years may be over, don't let that stop you — two lovely comets still sail the evening sky.

Comet extravaganza

In a normal year, observers would be thrilled to have a pair of comets glowing at 6th and 7th magnitude, let alone simultaneously. Granted, the July sky can't measure up to that of a couple months ago, when C/2001 Q4 (NEAT) and C/2002 T7 (LINEAR) were at their peaks, but that's a poor reason to stop observing comets. You now have a great opportunity to compare a pair of primordial snowballs to the wonders of deep space, like globular clusters and galaxies.

NEAT takes a dip

Comet C/2001 Q4 easily outshines all the "faint fuzzies" in Ursa Major. Seeing the bright spiral galaxy M81 without binoculars is an ultimate challenge even for sharp-eyed observers. In comparison, Q4 should glow a magnitude brighter. For binocular users, it will be a snap to find, located in the same field as the Big Dipper's pointer stars. A chart for the comet's position this month appears on page 63.

How long will you be able to spot Q4 without optical aid? Try to get as far away from city lights as possible, perhaps during an outdoor vacation. The middle two weeks of July will be best because there won't be any added glare from moonlight. If you've been staring at a campfire, remember to take 15 to 30 minutes to adapt more fully to the darkness before making an attempt.

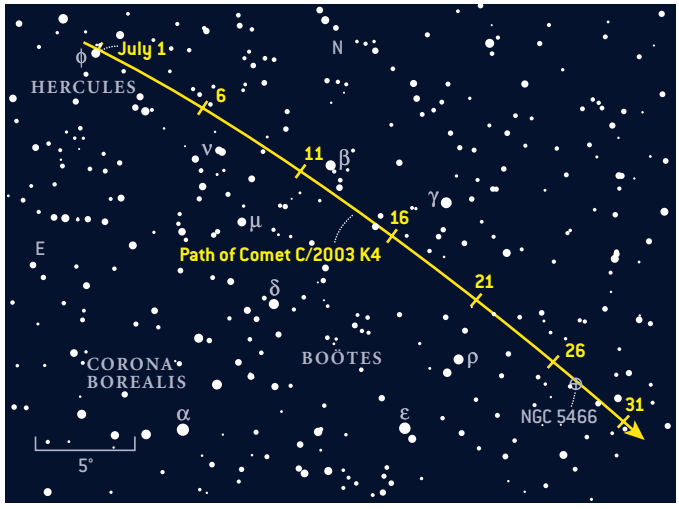
When you compare Q4 to the nearby Messier objects M97, M108, and M109, you'll see right away how impressive comet Q4 still is. Its shape and brightness profile look distinct, with a noticeable bow shock and an elongated tail.

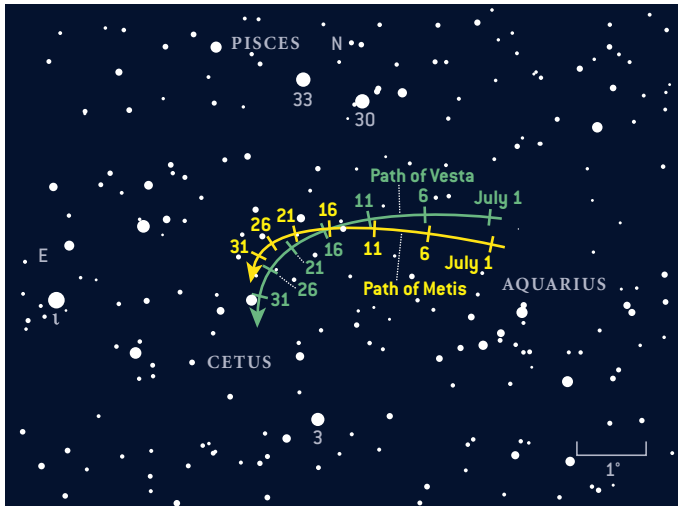
K4 tussles with globs

A 7th-magnitude comet is great to compare with globular star clusters. Both comets and globulars can be round and fuzzy, but that's usually where the similarity ends. Swing your binoculars from the bright Hercules cluster, M13, up to M92, and back to Comet C/2003 K4 (LINEAR). Next, slide south for a view of M3 and M53. You'll find M53 tougher to see than K4, but it probably appears most like the comet in size and brightness.

Now repeat your survey with a telescope. A 5-inch scope instantly reveals M3 and M13 as big balls of stars, in contrast to the milky, diffuse light coming from K4. In smaller scopes, look carefully at the edges of both the comet and the globulars to differentiate their characters.

An interesting alignment occurs on the evening of July 28, when K4 passes 15' (half the Moon's apparent size) away from globular star cluster NGC 5466. Unfortunately for visual observers, bright light from the nearly Full Moon takes away much of the charm. You'll have more success if you try to grab some images of the pair.





Vesta and Metis tango

Many observers enjoy watching objects in the solar system move. Too much of astronomy is frozen in the long timescale of the universe. This month, you can catch two space rocks simultaneously moving across the same star field. For three weeks, asteroids 4 Vesta and 9 Metis remain less than 30' apart. From July 13 to 18, they'll both fit in the same high-power eyepiece field.

Vesta glows at magnitude 7.0, while Metis appears three to four magnitudes fainter. The catch to this observation is that you need to wait until after midnight, when the pair rises above the murk of the eastern horizon. They currently lie on the tip of the snout of Cetus the Whale.

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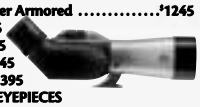

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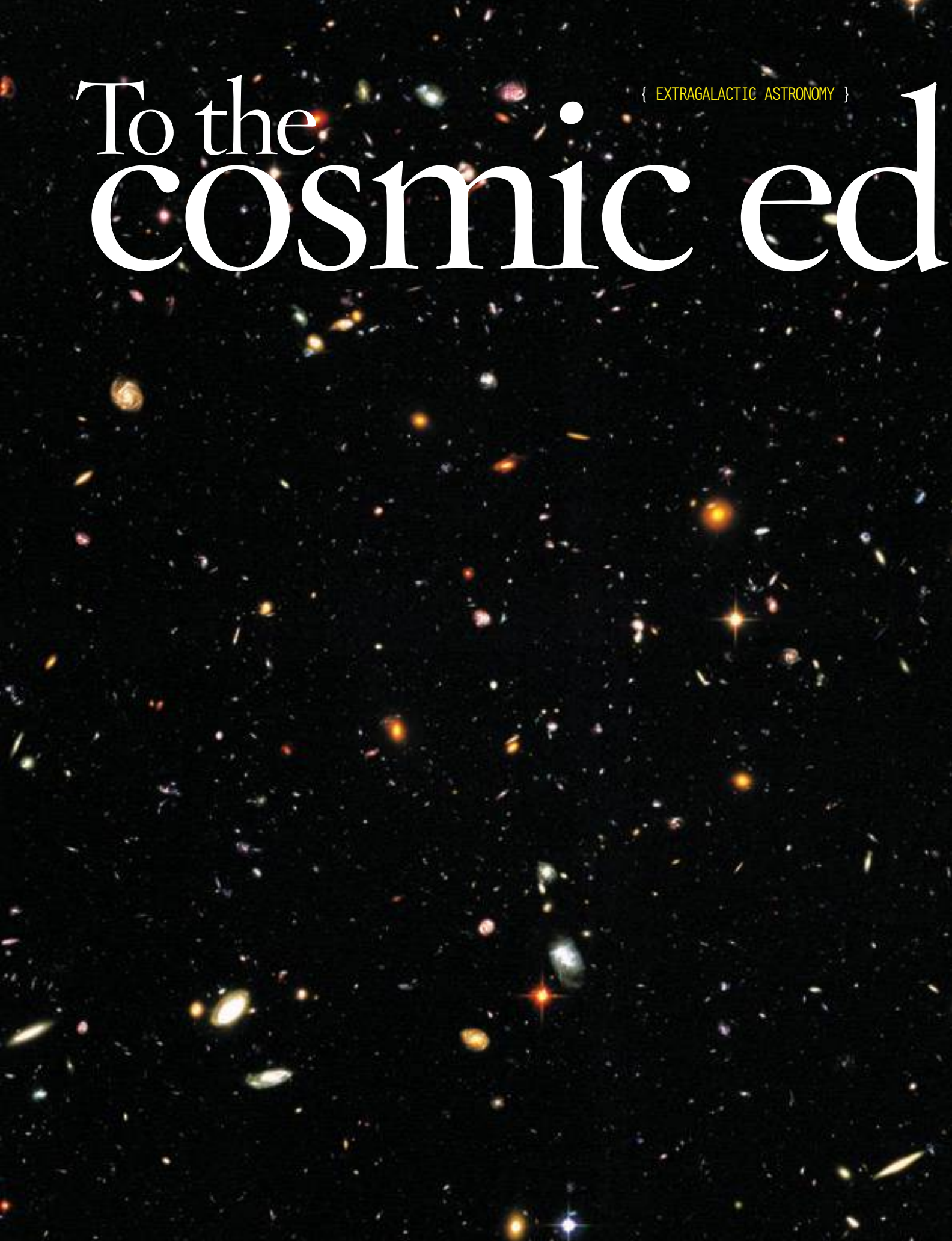
{ EXTRAGALACTIC ASTRONOMY }

To the cosmic ed



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Hubble captures the deepest view ever of the universe, finding 10,000 galaxies that stretch all the way back to the edge of space and time. /// BY FRANK SIETZEN, JR.

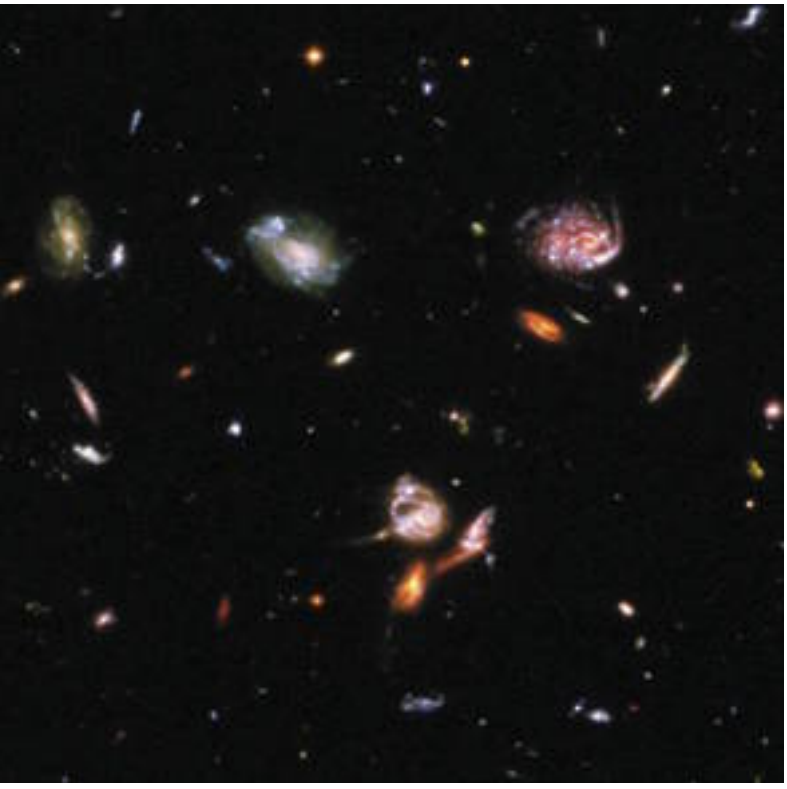
A long time ago, in a galaxy far, far away . . .

When George Lucas penned the opening to his epic saga more than a quarter century ago, little did he realize that the Hubble Space Telescope one day would turn his fantasy into reality. Or perhaps multiple realities would be closer to the truth — Hubble recently gave astronomers a spectacular view of some 10,000 ancient galaxies stretching to the edge of the visible universe.

Using a combination of the Advanced Camera for Surveys (ACS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), Hubble captured the deepest images ever of the cosmos. The release of these extraordinary

OBSERVING IN THE NEAR INFRARED, (above) Hubble sees some galaxies that existed just 400 million years after the Big Bang. The expansion of the universe shifts the light from these early galaxies into the near infrared. NASA, ESA, AND R. THOMPSON (UNIVERSITY OF ARIZONA)

THE HUBBLE ULTRA DEEP FIELD (left) provides the deepest portrait of the universe in visible light. It took Hubble nearly a million seconds to take this exposure, which records objects as faint as magnitude 30. NASA, ESA, S. BECKWITH (STScI), AND THE HUDF TEAM



1 **THREE GALAXIES DO BATTLE** (just below center) in the rough-and-tumble early cosmos, when the universe was smaller and collisions were much more common than today.

2 **A MAJESTIC SPIRAL GALAXY** highlights this section of the Ultra Deep Field. This big, bright galaxy is one of the nearest in the field, located "only" about 1 billion light-years from Earth.

JUST A FEW FOREGROUND STARS in the Milky Way (the objects with spikes) mar the HUDF view of 10,000 distant galaxies. The boxes shown here are keyed to close-up images above. ALL IMAGES: NASA, ESA, S. BECKWITH (STScI), AND THE HUDF TEAM

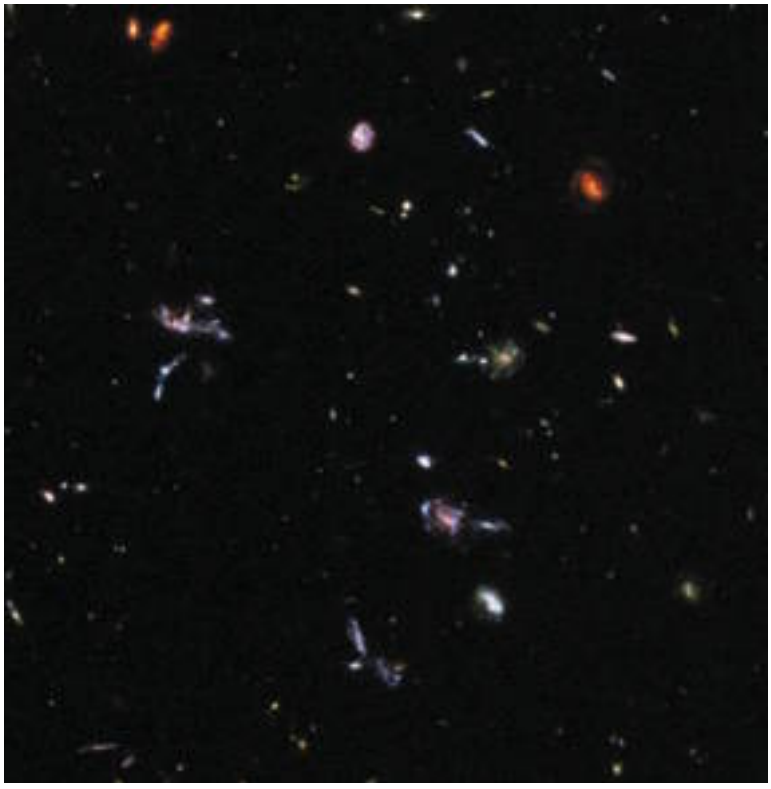
images, known as the Hubble Ultra Deep Field (HUDF), kicked off a global race to study their contents and to understand just what they reveal.

Astronomers estimate the HUDF shows about 10,000 galaxies, some apparently among the first galaxies to emerge from the cosmic "Dark Ages." This era, marked by a cold and opaque cosmos, ended about 400 million years after the Big Bang when the first generation of stars began to reheat the universe. "Hubble takes us to within a stone's throw of the Big Bang itself," says Massimo Stiavelli, an astronomer at the Space Telescope Science Institute (STScI) in Baltimore, Maryland, and leader of the HUDF team.

"This is the deepest picture we have ever had of the universe," adds STScI director Steven Beckwith. The HUDF contains the faintest objects ever seen, reaching down to magnitude 30 — some 10 billion times fainter than the faintest objects visible with the naked eye. At that sensitivity, Hubble could pick up the glow of a firefly on the Moon.

It's also two to four times fainter than Hubble's Wide Field and Planetary Camera 2 achieved in the two landmark Hubble Deep Fields, taken in 1995 and 1998. Galaxies evolved so quickly in the early universe that the most significant changes occurred within a billion years of the Big Bang. "Where the Hubble Deep Fields showed galaxies when they were youngsters," says Stiavelli, "the Ultra Deep Field reveals them as toddlers, enmeshed in a period of rapid developmental changes."

Frank Sietzen, Jr., *is coauthor of* New Moon Rising: The Making of George W. Bush's Space Vision and the Remaking of NASA, *which was published in June by Apogee Books of Canada.*



3 **CLOSE INTERACTIONS SHREDDED** many of the galaxies in this part of the field, chronicling a period when the cosmos was much younger and more chaotic than what we see today.

4 **SEVERAL SMALL, REDDISH GALAXIES** in this section appear to be among the most distant ever seen in visible light, existing perhaps just 700 million years after the Big Bang.

The ACS image was built from 800 exposures, two captured in each of 400 separate Hubble orbits around Earth. The images were taken over a four-month period that began on September 24, 2003, and ended on January 16, 2004, and represent a total exposure time of 11.3 days, or nearly 1 million seconds. (Still, that's but a small fraction of Hubble's total observing time during this period.)

Astronomers aimed Hubble at a pencil-thin slice of sky in the northeastern corner of the constellation Fornax the Furnace, a region that appears virtually empty in ground-based photographs. The square field measures 3' on a side, one-tenth the diameter of the Moon. (That's twice the field of view of the Wide Field and Planetary Camera 2, and the ACS has a greater sensitivity as well.) "It would take 13 million of these HUDF fields to cover the entire sky," says Beckwith, and nearly 1 million years of uninterrupted observing time to go as deep.

The final ACS view combines images made through four different filters. It takes astronomers back to about 700 million years after the Big Bang. Galaxies of various sizes, shapes, colors, and ages emerge in this view. The bigger and brighter galaxies — the ones nearest Earth — appear to be classic spirals and ellipticals. But lots of oddball galaxies litter the field, including some that look like toothpicks and others that resemble links on a bracelet. The smallest, reddest galaxies, about one hundred of which appear in the image, may be among the most distant ever seen.

The NICMOS image covers a slightly smaller field than the ACS image, about 2.4' on a side. It was created from views at two near-infrared wavelengths and represents 4.5 days of total exposure time.

Although the NICMOS view shows many of the same galaxies that appear in the ACS image, it also reveals some that lie even farther away. The expansion of the universe stretches much of the visible and ultraviolet light emitted by the most distant galaxies into the near-infrared part of the spectrum, where NICMOS picks it up. Rodger Thompson of the University of Arizona, principal investigator for NICMOS, thinks the image may show galaxies that existed just 400 million years after the Big Bang. If that age is confirmed, it would mean we are seeing the universe when it was just 3 percent of its present age.

In the weeks, months, and years of study ahead, astronomers hope to learn much more about the galaxies in the HUDF — and the birth and evolution of galaxies in general. The images mark the deepest penetration Hubble will ever achieve, and they will stand as the most distant views of the cosmos until the advent of NASA's James Webb Space Telescope, an infrared-optimized, 6.5-meter telescope currently scheduled for launch in 2011.

The HUDF images also gave renewed strength to efforts to prolong Hubble's life. "This is a stunning example of why the world loves Hubble," said Senator Barbara Mikulski (D-MD) at the image unveiling in Baltimore. Soon after the HUDF images were released, NASA Administrator Sean O'Keefe chartered the National Academy of Sciences to review his decision not to fly a fifth and final shuttle servicing mission to the orbiting observatory — and to see whether a robotic mission might be able to preserve the aging spacecraft.

To learn more about the Ultra Deep Field and Hubble's original Deep Field images, visit www.astronomy.com/toc

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Customer Quote of the Month #148

We ship Meade LX200GPS go-to scopes from *our* stock.

Meade 8" LX200 GPS SMT **$2195**

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A Meade LXD55 makes astronomy easy.

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Meade 8" SN-8 f/4 reflector **$839**

We actually stock TeleVue. Does your dealer?

NP-101 **$3595**

To sell seven figures worth of TeleVue a year, you have to keep a lot of it in stock so you can ship fast and keep your customers happy. We *do* keep a big inventory on hand, so our customers are *very* happy. Other dealers may say they carry TeleVue, *but we actually keep TeleVue in stock.* Lots of it.

Here are a few of the TeleVue refractors that we keep in stock for immediate shipment.

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TV-76, 3" f/6.3 apo **1675.00**
TV-85, 3.35" f/7 apo **2080.00**
TV-102, 4" f/8.6 apo **2635.00**
Renaissance 102, 4" f/8.6 brass apo **3175.00**
NP-101, 4" f/5.4 apo **3595.00**

All of the above refractors come without a mount, but include an eyepiece (except the NP-101), an enhanced aluminum or 99% reflectivity Everbrite star diagonal, a carrying case, and a tube ring for mounting. Optical tubes only, without these accessories (such as the new **TV-60** apochromatic at $795), are also available from stock.

As for accessories, we stock them all. For example, here are a few of the newest eyepieces from TeleVue that we can ship today.

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11mm 1.25" Nagler Type 6 ..... **280.00**
20mm 2" Nagler Type 5 ..... **440.00**
41mm 2" Panoptic **495.00**

Whether it's a Gibraltar, Panoramic, or Tele-Pod mount; a Sky Tour computer; a Nagler, Radian, Panoptic, or Plössl eyepiece; a Powermate or Barlow; an Everbrite 99% reflectivity star diagonal; a light pollution filter, or a BinoVue – if it's TeleVue, it's in stock.

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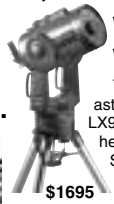

$1695 Meade 8" LX90

The **Meade LX90** lets you enjoy go-to astronomy for not a lot of money. The 8" LX90 costs only $1695. It comes with a heavy-duty adjustable height tripod, Super Plössl eyepiece, Autostar computer with 30,223 star and object memory, and an 8 x 50mm finder.

Some dealers don't even stock the telescopes they sell. Why wait for one of those non-stocking dealers to get around to ordering an LX90 for you to enjoy? The LX90 is almost always in stock at ***astronomics.*** We had over a dozen in inventory as this was written, so you can probably get *your* LX90 from us with little or no delay.

Compact enough to travel, big enough for serious seeing.

5" ETX-125EC **$995**

Best-selling **Meade ETX Maksutov-Cassegrains** are compact enough to take with you and use anywhere – from light-polluted city or suburb to dark sky sites. And their superb optics will keep you happily observing for years. Prices start at $595 for a 3.5" go-to scope with everything you need to start observing as soon as you get it. Each has an adjustable height tripod; an Autostar computer with a memory of 30,223 stars, deep space objects, and planets it can find and track for you; finderscope; 26mm Super Plössl eyepiece; and more.

A compact and easy-to-use Meade ETX Maksutov makes astronomy easy – and we have them all in stock now!

Big binoculars. Bright images. Little prices.

$349

You don't need a telescope to enjoy astronomy. Many of the wonders of deep space – nebulas, galaxies, and star clusters – are all visible through Celestron binoculars, as are myriad craters and mountains on the Moon.

The **15 x 70mm Skymaster**, left, shows you detailed views of the night sky for *very* little cash.

$89

The **10 x 50mm LPR Optiview**, left, is a good conventional binocular that also has a secret weapon for astronomy – built-in light pollution filters to block the glare of city lights that can wash out faint deep space nebula detail.

$99.95

The big **25 x 100mm Skymaster** shown above (which has the light-gathering power of two 4" telescopes, one for each eye), and the similar but physically smaller **20 x 80mm Skymaster** at $279, not shown, gather huge amounts of light for serious deep space views. All Celestron Skymaster binoculars include an adapter for use on a photo tripod.

Celestron starter scopes packed with features and value.

8" f/6 StarHopper **$369**

The new **Celestron StarHopper Dobs** are loaded with useful features. Instead of Teflon or plastic pads sliding on Formica to support the scopes, roller bearings with dozens of support points ride on a broad azimuth track for smooth hitch-free horizontal motion. Altitude bearings ride on nylon rollers for an equally smooth vertical motion. There's a variable tension altitude clutch to compensate for different eyepiece weights. The finderscopes (6x30mm on the 6"; 9x50mm on the 8" through 12") are mounted in easy-to-align quick release brackets. The 8" through 12" scopes use a 2" metal rack and pinion focuser (with 1.25" adapter) and come with a 2" 32mm E-Lux eyepiece (the 6" scope has a 1.25" metal rack and pinion focuser and 25mm Plössl). The 10" and 12" scopes have a built-in battery-operated cooling fan for their primary mirrors. All have fast cool-down metal tubes and BK7 optical glass mirrors.

Here are the prices for the fully-equipped Celestron StarHopper Dobsonians.

6" f/8 Celestron StarHopper ... **$249.00** + $49 freight
8" f/6 Celestron StarHopper ..... **349.00** + $59 freight
10" f/5 Celestron StarHopper .... **499.00** + $69 freight
12" f/5 Celestron StarHopper .... **849.00** + $99 freight

Big right angle finders. New lower prices.

Antares 12 x 80mm **$174.95**

We stock **Antares** 8 x 50mm and 12 x 80mm right angle finders at new lower prices from $79.95 to $239.95. Choose from Celestron black, Meade blue, or a gloss white in either standard mirror-image versions or erect right-reading models that show you the sky the way it appears on star charts. Each is available with either dark crosshairs or a unique built-in cordless red disk illuminator. Economical optional quick release mounting brackets are also available.

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This month's featured products . . .

Astrozap metal dewcaps for Celestron/Meade.

Astrozap dewcaps are made of durable welded seam aluminum. Exteriors are finished in a long-lasting baked powdercoat that matches the color of your scope's optical tube. Interiors are lined with black felt to reduce moisture and keep off-axis light from reaching the optics. Nylon thumbscrews in heavy duty threaded metal inserts lock the dewcap securely on your telescope's front cell. (No thumbscrews are required for the retractable ETX dewshields.) Dewcaps are available for the following scopes:

Celestron 5", black, orange, or white ..... **$75**[00]
Celestron 8", black, gray, or orange ..... **125**[00]
Celestron NexStar 8 GPS only, gray ..... **$125**[00]
Celestron 9.25", black or gray ..... **135**[00]
Celestron 11", black, gray, or orange ..... **175**[00]
Celestron 14", black, gray, or orange ..... **245**[00]
Meade ETX-90, black ..... **39**[95]
Meade ETX-105, black ..... **45**[95]
Meade ETX-125, black ..... **49**[95]
Meade 6" LXD55 SN-6, white ..... **75**[00]
Meade 8" LXD55 SC-8/SN-8, white ..... **125**[00]
Meade 10" LXD55 SN-10, white ..... **140**[00]
Meade 7" Maksutov/8" SCT, blue ..... **125**[00]
Meade 10" SCT, blue ..... **140**[00]
Meade 12" SCT, blue ..... **190**[00]
Meade 14" SCT, blue ..... **245**[00]
Meade 16" SCT, white ..... **325**[00]

Only $995 for a 5" GPS-ready Celestron SCT.

The **Celestron NexStar 5i** is the *only* 5" telescope to have a fully automatic GPS go-to computer available as an option. No other 5" scope has GPS! The NexStar 5i has a computer hand control with a 45,000+ star and object database, adjustable height tripod, red dot finder, eyepiece – everything you need to start observing immediately!

Multicoated optics are *standard equipment* with the Celestron NexStar 5i, not an option as with other scopes. NASA uses Celestron 5" multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium image quality? **$995**

the Nexstar 5i is shown with optional photography accessories

NexStar 5i

Our *38* light pollution filters make bright skies dark.

City lights wash out your view of the skies? Improve your deep space observing by dimming those annoying lights with one of the many light pollution reduction filters we stock.

We have two **Celestron** broadband filters. One is designed for 1.25" eyepieces; the other for Schmidt-Cassegrain (SCT) rear cells.

We have 13 **Lumicon** Deep Sky broadband, UHC narrowband, and H-Beta and Oxygen III line band filters for use in 1.25" and 2" eyepieces, as well as on SCT rear cells.

We have six **Meade** broadband, narrowband, and Oxygen III filters in 1.25" eyepiece and SCT rear cell versions.

We have four **Sirius** contrast enhancement and nebula filters for 1.25" and 2" eyepieces, plus a unique 1.25" *variable* nebula filter.

We have four **TeleVue** Bandmate NebuStar UHC-type narrowband and Oxygen III line band filters in both 1.25" and 2" eyepiece versions.

We have eight **Thousand Oaks** broadband, narrowband, Oxygen III, and H-Beta filters in both 1.25" and 2" eyepiece versions.

Some dealers carry only a few filters to reduce the effects of light pollution. We carry 38. We have one that's exactly right for you.

We have a Meade extended service contract for you.

Meade Sky Assurance Program

You can get a Meade Sky Assurance™ extended service plan from us – *even if you didn't buy your scope from us!*

Meade's new Sky Assurance™ service contracts extend Meade's standard telescope warranty from one year to a total of either three or five years. Sky Assurance™ service contracts cover all parts and labor costs due to defects in workmanship and materials *(including normal wear and tear!)* If the product can't be repaired, it will be replaced. There is no deductible for any covered repair.

You can enroll for extended service when you buy your telescope, or as late as one month before the expiration of the normal warranty period. In other words, you have eleven months from the date of purchase to decide whether you want to extend your warranty. Each extended service contract is effective from the date you bought your telescope.

Meade Sky Assurance™ also offers optional Advance Shipping Upgrades for the extended service contracts. If you choose this option, you'll be sent a shipping container for your defective scope with instructions on how to pack and ship the scope to the Meade Service Center at no cost to you. Shipping costs in both directions are covered under this option.

Sky Assurance™ extended service contracts are renewable in three or five year increments for as long as you own your telescope. In addition, they are transferable to a new owner, should you sell your telescope while it is covered by a contract. Here's a sample of the 3-year Sky Assurance™ prices for some popular Meade scopes.

ETX-90, 3-year Sky Assurance ..... **$64**[99]
LX90, 3-year Sky Assurance ..... **144**[99]
8"/10" LX200, 3-year Sky Assurance ..... **244**[99]
12"/14" LX200, 3-year Sky Assurance ..... **329**[99]
16" LX200, 3-year Sky Assurance ..... **1349**[99]
3-year Advance Shipping Upgrade ..... **129**[99]

Full Meade Sky Assurance™ details are on our website, along with the 3-year and 5-year extended service pricing for all Meade scopes from under $199.99 to $16,999.99.

Hot scopes and accessories from William Optics.

$130

How much would you pay for a 97% reflectivity 1/10th wave accuracy 2" enhanced aluminum mirror diagonal with a 1.25" eyepiece adapter? Some competitors charge up to $250 for that combination. But the **William Optics** 2" diagonal shown above (our part #W2) is only $130!

A 2" *99% reflectivity* 1/10th wave accuracy *dielectric* mirror diagonal for Schmidt-Cassegrains, with 1.25" eyepiece adapter, costs $360 from a competitor. But the William Optics 2" dielectric diagonal to the right (our #W2DSCT) is only $230!

$230

The 2" rotatable Schmidt-Cassegrain zero image shift Crayford-style manual focuser with 1.25" eyepiece adapter to the left (our #WSCTF) is only $149. As with all William Optics scopes and accessories, it offers exceptional value – fine optical performance and quality mechanics, at a price less than similar competitive products.

$149

The **William Optics Megrez 80 II APO** *fluorite triplet* 80mm f/6.25 apochromatic refractor optical tube to the right has outstanding optics – truly excellent color correction, very high contrast, tack sharp images – for *$200 less* than a competitive triplet apo that's similarly equipped. It's just another example of the exceptional value of the many unique William Optics products we stock.

$1595

Get your go-to *now.* We ship Celestrons from stock.

Why wait for another manufacturer to build and ship your scope to you? We ship **Celestron Advanced Series** go-to telescopes from *our* stock daily. These full-featured Celestron scopes put multicoated optics on an easy-to-use go-to mount. From a 5" Schmidt-Cassegrain (with optics so good that NASA flies them on the Space Shuttle) to a 10" reflector, there's a Celestron go-to scope that's right for you and your budget. Available scopes include:

a 6" Newtonian reflector ..... **$799**[00]
an 8" Newtonian reflector ..... **1019**[00]
a 6" achromatic refractor ..... **1069**[00]
a 5" Schmidt-Cassegrain ..... **1099**[00]
a 10" Newtonian reflector ..... **1199**[00]
an 8" Schmidt-Cassegrain ..... **1359**[00]
and a 9¼" Schmidt-Cassegrain ..... **1779**[00]

Each Celestron Advanced Series go-to has a heavy duty adjustable height tripod with stable 2" diameter steel legs instead of the lighter aluminum legs on competitive scopes. Built-in computers take the guesswork out of finding your way around the skies. They find and track over 45,000 stars and objects for you, compared to 30,000 for the competition. And multicoated optics are standard, not an optional extra.

Celestron C8S-GT 8" go-to

$1359

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Denkmeier Binoviewers are optimized for *your* scope.

Use both eyes to observe through a **Denkmeier Binoviewer**, and you can see up to 40% more detail than you can when looking through a single eyepiece. Your views of the planets, Moon, and deep space objects become almost three-dimensional.

Whether you have a refractor, reflector, or a Schmidt-Cassegrain, there is a Denkmeier Binoviewer with specialized optics that are optimized to give you peak visual performance with your scope's particular optical design. Prices start at $599.

There's nothing mysterious about *this* Sphinx.

The **Vixen Sphinx** telescopes and mounts take the mystery out of go-to astronomy. You don't have to know Messier, NGC, or IC numbers to have your scope find deep sky objects.

Simply move the crosshair cursor over the object displayed on the Star Book hand control's 4096-color LCD star chart screen. Push a button and the Sphinx mount moves to that object. Zoom-In/Out buttons for the star chart display also control the motor speed. As you zoom in on an object displayed on the screen, the motor speed automatically slows for more accurate control. Zoom out and the motor speed increases to cover large distances more quickly.

Vixen Star Book hand control showing star chart display

The Star Book's 4MB flash ROM memory can be updated from the Internet to keep you current with the heavens. And the easy-to-use Star Book can be used as a stand-alone star atlas to let you learn the skies anywhere, anytime.

The Sphinx go-to mount with Star Book controller is available separately for use with your own optics. It is also available in premium Vixen telescope/mount packages that range from a 3.1" f/5 refractor on a supremely portable tabletop go-to mount to big 8" reflectors and catadioptrics on full length field tripods.

$3910
FL80SWT-SXW
3.1" f/8 fluorite apo Vixen refractor on Sphinx go-to mount

You'll find full Vixen Sphinx details and prices on our **www.astronomics.com** website.

Buy one Power Tank instead of hundreds of batteries.

Most telescopes today run on flashlight batteries. Instead of buying eight new batteries every few weeks, buy one **Celestron Power Tank** rechargeable battery instead. 7 and 17 amp-hour Power Tanks have the power you need to run your scope all night long and can be recharged hundreds of times. They have *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; built-in recharger; shoulder strap; and more. The 7AH Power Tank is only $59[95]. The 17AH is $109.95. A similar competitive dual output 17AH battery – *with fewer features* – costs $204. Why pay far more for a battery that does far less?

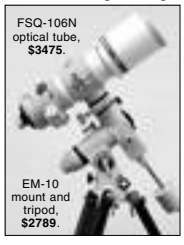
Takahashi premium fluorite apo optics are on sale.

If there's anything better than the superb optics of a **Takahashi** *fluorite apochromatic* refractor, it's the speed at which you can get Takahashi optics from our stock. And even better than the fast delivery are the sale prices on Takahashi's best-selling optical tubes.

Regularly $1379, the 3.1" **FS-78** fluorite doublet is sale priced at **$1195!** You save $184!

Takahashi's unique 90mm f/5.6 **Sky 90 II** is sale priced at **$1849!** Regularly $2279, you save $430! *Sky & Telescope* called this compact scope "an ideal travelscope for mobile observers, providing maximum performance at minimum size."

The latest 4" **FS-102 II** fluorite doublet with sliding dew shield is **only $1895**! Regularly $2349, you save $454!



FSQ-106N optical tube, **$3475**.

EM-10 mount and tripod, **$2789**.

The 5" **FS-128** fluorite doublet is **only $4495**! Regularly $5249, you save $754!

Finally, the big 6" **FS-152** fluorite doublet optical tube is on sale for **only $6995**! Regularly $9329, you save $2334!

We also stock the compact 22" long Takahashi **FSQ-106N** 4" f/5 four-lens *dual fluorite* astrograph apo with 4" focuser, shown to the left on an optional mount.

If you want a premium apo refractor at a money-saving sale price, and you want it without a lo-o-o-ng wait, the refractor you want is a Takahashi from ***astronomics***.

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ASK ASTRO

Star age versus light travel time, space dust and molecular clouds

OF TIME AND SPACE

I look at stars and think about them

being millions of light-years away from us, but how do we know if they are still there, since it takes millions of years for the light to reach us?

— ROBERT JACOBS

SPIRAL GALAXY NGC 300 lies 7 million light-years away. Its most luminous stars will die before their light can traverse this distance. ESO

Strictly speaking, we do not and cannot absolutely know if the stars are really still there because we can see them only by their light, and this light, as you say correctly, takes some time to get to us. Nonetheless, we are rather confident the stars within our galaxy are still there. On the other hand, stars outside our galaxy may not be. A detailed answer to your question depends on both the masses of the stars and their distances.

Our galaxy is "only" about 100,000 light-years across. Any stars you see in our galaxy will be closer than this distance, and less than about 100,000 years have passed since the light left them. For example, the distance to Sirius is only 8.6 light-years, the distance to Vega is about 25 light-years, and the distance to Polaris is 680 light-years. Most of the light you see from nearby stars is only a few hundred years old. By comparison, the most massive, shortest-lived stars will shine for millions of years, and solar-type stars will shine for billions of years. Typical stellar lifetimes are much longer than the time it takes for the light to reach us. As a result, although some delay occurs, we can see stars within the galaxy more or less as they actually are.

The situation changes when you look at stars outside the galaxy. Our nearest neighboring galaxy is M31 in Andromeda, about 2.9 million light-years away. The time it takes for starlight to travel to us from the Andromeda Galaxy is a significant fraction of the total lifetime of a massive star. So, if you look at a massive star in M31 — you would need a decent-size telescope to do so — it's unlikely the star still exists by the time you see its light. Instead, the star would be scheduled to end its life in a spectacular explosion known as a supernova. On the other hand, solar-type stars live for billions of years before they turn into red giants near the ends of their lives. When we view such stars in the Andromeda Galaxy, we expect them still to be around today.

The story changes again when you consider starlight from distant galaxies in deep space, up to 10 billion light-years away. The time required for this light to reach us is roughly the same as the hydrogen-burning lifetime of our Sun and other solar-type stars, so these stars generally die during the time between when the light was emitted and when it is observed here on Earth. However, our universe is still relatively young compared to the lifetimes of the smallest stars. These tiny red dwarfs, with 10 to 30 percent the mass of

our Sun, will live for trillions of years until they turn into blue dwarfs — and eventually white dwarfs on their deaths.

Such stars will evolve little during the time it takes their light to travel across the entire observable universe. Because light takes so long to reach us from the distant realms of the cosmos, and because the universe continues to expand, there is some ambiguity regarding the distance to far-away galaxies. By convention, when we say a distant galaxy is "10 billion light-years" away, we mean that it's that far away *now*. In the distant past, when the light we see now was emitted, the galaxy was much closer to our location.

Of course, in those dim ages of the past, our solar system, which is just 4.6 billion years old, did not yet exist.

— FRED ADAMS, UNIVERSITY OF MICHIGAN

THE LOWDOWN ON SPACE DUST

How dense is the interstellar dust that obscures our view of the galactic center? Also, what is this dust?

— BRAD GREENBURY, FRESNO, CALIFORNIA

The typical density of interstellar gas in our Milky Way Galaxy's disk is close to one hydrogen atom per cubic centimeter. When we move into intergalactic space — the space between galaxies — the density drops to about one atom per cubic meter. The Sun and solar system currently are moving through a void in the interstellar medium called the "Local Bubble," which has a density of only 0.05 to 0.1 atom per cubic centimeter. However, in some regions of space, gravity has collected the interstellar gas and dust into relatively dense clouds that contain from about 100 to more than a million atoms per cubic centimeter. Because the dust blocks and absorbs incident light, these clouds are opaque and relatively cold, with temperatures only about 10 degrees above absolute zero. Their hydrogen and other elements tend to form molecules, hence these objects are called "molecular clouds."

Interstellar dust accounts for about 1 percent of the mass of the interstellar medium and its molecular clouds. These tiny grains contain anywhere from a few hundred to billions of atoms and have sizes from tens of Ångstroms to more than 10,000 Å (1 micron). Grains have a variety of compositions including silicate minerals (oxides of silicon, magnesium, aluminum, etc.), carbon compounds (graphite and so-called polycyclic aromatic hydrocarbons), and metal oxides. In cold molecular clouds, various gases (water vapor, carbon monoxide, carbon dioxide, etc.) can collect and condense on these cores to form icy mantles.

At visual wavelengths, molecular clouds obscure background stars by at least several magnitudes of extinction. Such clouds are responsible for the "Great Rift," a dark lane that splits the summer Milky Way from Cygnus to Sagittarius. The center of the Milky Way contains some of the most massive and dense molecular clouds found anywhere in the galaxy. When we look toward the heart of our galaxy, our view is blocked by more than 30 magnitudes at visual wavelengths. However, because interstellar grains are smaller than the wavelength of light, they become more transparent toward the red and infrared portions of the spectrum. We can begin to penetrate our galaxy's dust clouds — and "see" the galactic center — with telescopes sensitive to wavelengths longer than about 2 microns. **— JOHN BALLY,** UNIVERSITY OF COLORADO AT BOULDER

LIKE AN INK STAIN on the starry sky, molecular cloud BHR 71 harbors several young, embedded stars. A jet formed by one of these stars has broken out of the cloud at center. BHR 71 is about 1 light-year across. ESO

Explore unseen worlds through the eyes of artists trained to understand what might be beyond the reach of telescopes. /// ANDREW FAZEKAS

Visions of space

Imagine having a ringside seat to the most terrifying cosmic events and watching breathtaking panoramic views unfold. From a precarious vantage point on a desolate rocky world, see a nearby galaxy spewing powerful jets of hot gases from its core, or watch as a far-off supernova explosion rips apart a fledgling system of planets, sweeping their remains into interstellar space. Such experiences are beyond the capabilities of earthbound telescopes and space probes currently exploring our solar system. But imaginative space artists simulate these environments, allowing anyone to take vicarious journeys through the cosmos.

What is space art?

A fusion of science and fine art, "space art" both educates and fascinates. Astronomical illustration anticipates future interplanetary and interstellar travel as well as recreates historic events marking humans' major accomplishments in space exploration. Space art transports us to incredibly lethal environments forever beyond our technological reach. Nevertheless, as recognized space artist and gallery owner Kim Poor remarks, "Good space art makes you want to go there."

The work of space artists requires knowledge of astronomy, geology, space technology, hardware, or even astrobiology. The artistic ability to place these scientific disciplines on canvas, to transform the coldness of science into a uniquely human experience, makes space artists indispensable. Lynette Cook, well known for her depictions of extrasolar planets, says, "We artists have a great deal of art and science education and knowledge behind us that enables us to know what to paint and how to paint it." Armed with creativity and scientific knowledge, space artists illuminate new ideas for both the scientific community and the public.

But the exponential leap in the amount of data being gathered actually can make it harder for space artists to maintain accuracy in their work. William K. Hartmann, NASA planetary mission scientist and noted space artist, thinks it's left to the artist to combine all the lines of scientific evidence to picture unknown and exotic places. Ron Miller, who has been illustrating astronomical scenes for almost three decades, says, "The more we know about a place, the more difficult it is to depict because there are more constraints on the imagination."

Miller believes a high level of accuracy is important in his astronomical artwork, but not at the expense of the understanding of its intended audience. Sometimes the larger truth requires compromises. Miller recently created a painting of Saturn as seen from one of its moons for some students. From this vantage point, the rings appear only as a thin white line bisecting the planet, which was confusing to many students. "Strict accuracy was preventing an important piece of information from being assimilated," Miller explains. He realized if he tipped the rings just a little, all was understood.

Evolution of space art

Art and astronomy have been intrinsically linked for centuries. Astronomers have spent hours viewing fuzzy planets and transferring observations into meticulous drawings for later analysis. The first attempts at imaginative space-art were pure whimsy, expressing aspirations of space flight, and not based on hard science and engineering concepts. The late 19th century saw the first scientifically illustrated lunar landscapes in British, American, and French books and periodicals.

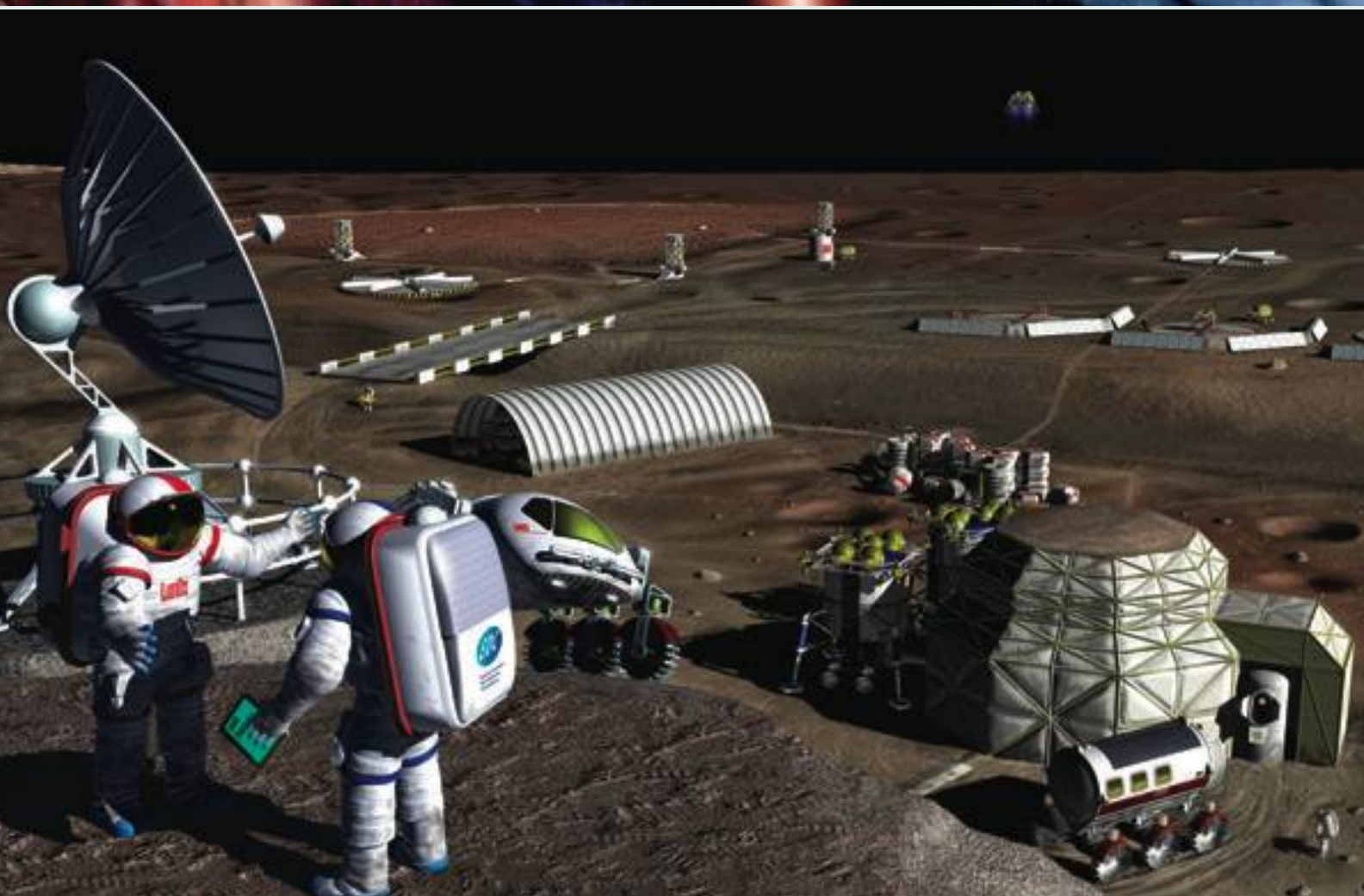
More than fifty years ago, David Lasser's visionary book, *The Conquest of Space*, became the flash point in the space-art movement. For the first time, this book about space travel depicted astronauts on spectacular extraterrestrial worlds. The legendary Chesley Bonestell, considered the grandfather of space art, provided scenes of manned expeditions to Mars, cartwheel-shaped space stations, and needle-nosed spaceships on the Moon. His ability to paint astronomical scenes with prophetic realism was renowned, and his art often was mistaken for photographs.

The number of space artists has grown since Bonestell's day partly from increased interest in space travel. In the pioneering heyday of space exploration, "artistic renditions" issued with media reports captured the public's attention. Space artists offered sights and destinations with an edge of realism never before possible. Today, dozens of internationally recognized space artists exist, and museums and planetaria display the works of established artists such as Michael Carroll, Don Davis, Dan Durda, Bob Eggleton, David Hardy, Paul Hudson, Pamela Lee, Jon Lomberg, Robert McCall, Mark Paternostro, Adolf Schaller, and Joe Tucciarone.

A BLACK HOLE (top right) in the center of a galaxy shoots jets of material culled from its accretion disk. DON DIXON

MINING THE MOON (bottom right) for oxygen from volcanic soil might support an extended human presence there. PAT RAWLINGS

Andrew Fazekas *is a freelance science writer and avid space-art collector. In a previous article for* Astronomy *(December 2001), he reviewed* The Art of Chesley Bonestell.



AN EXTRASOLAR PLANET on a highly elliptical orbit passes close to its star, causing the planet's oceans to boil. FROM *FARAWAY WORLDS* BY PAUL HALPERN, ILLUSTRATED BY LYNETTE COOK

Types of space art

Artists explore the remarkable symmetry as well as the puzzling irregularities of planetary landscapes that scientists are probing with robotic spacecraft. Styles range from realist to expressionist, and interpretations vary from literal to fantastic. Subject matter spans from gamma-ray bursts to large, Jupiter-like worlds circling distant stars. Many space artists create awe-inspiring, detailed landscapes. Tucciarone, for example, produces amazing scenes of cratered terrain, while Miller is known for his eerily realistic, icy, alien panoramas. Their pristine visions of utter desolation at the boundaries of known science — with no sign of humans anywhere — are true frontier art, harkening back to the masterpieces of the American frontier.

THE SOLAR NEBULA, (top left) a cloud of interstellar gas and dust, coalesced about 4.6 billion years ago. WILLIAM K. HARTMANN

THIS ABSTRACT IMAGE (bottom left) was created as concept art for space sequences in the movie *Contact*. JON LOMBERG

The trademark of Bonestell — spacecraft and associated hardware with alien-world backdrops — is carried on today by such artists as Hardy, Hudson, Lee, and Rawlings. "Hardware art" is a true specialty within the space-art genre. But while machinery may be the focus of many of these pieces, artists like Rawlings take great care in rendering highly realistic settings to keep the work credible.

Abstract art affords its creators true artistic license, producing many engaging pieces. Kara Szathmary and Jon Lomberg, for example, create delicate and thought-provoking works expressing the interaction of human feelings with science.

Space artists use a variety of media including airbrush, oils, acrylic, and even computers. Some produce entire works digitally, without ever holding a paintbrush in hand. For artists who use the canvas of the screen to paint virtually, computers allow greater experimentation with color, lighting, and setting. "Digital methods have been wonderfully liberating," says Don Dixon, art director of the Griffith Observatory in Los Angeles. "Not only do they permit my work to be finished more quickly, but the ability to save multiple versions of an illustration is soothing to the soul." At the same time, Dixon has not given up traditional media, using oil on canvas to paint private commissions.

Artistic talents

Despite advances in science and technology that provide us with portraits of mysterious celestial structures, the uniquely human ability of imagination remains the foundation of today's space artists. Capturing the beauty of the stars for more than a hundred years, paintings of space continue to inspire the next generations of explorers and scientists. Over the bleak canyons of Mars, by the frigid geysers of Neptune's moon Triton, and through the perilous rings of Saturn, space artists explore the universe with their paintbrushes, blazing a trail for humans to follow. A

Learn more about astronomical artists at www.astronomy.com/toc

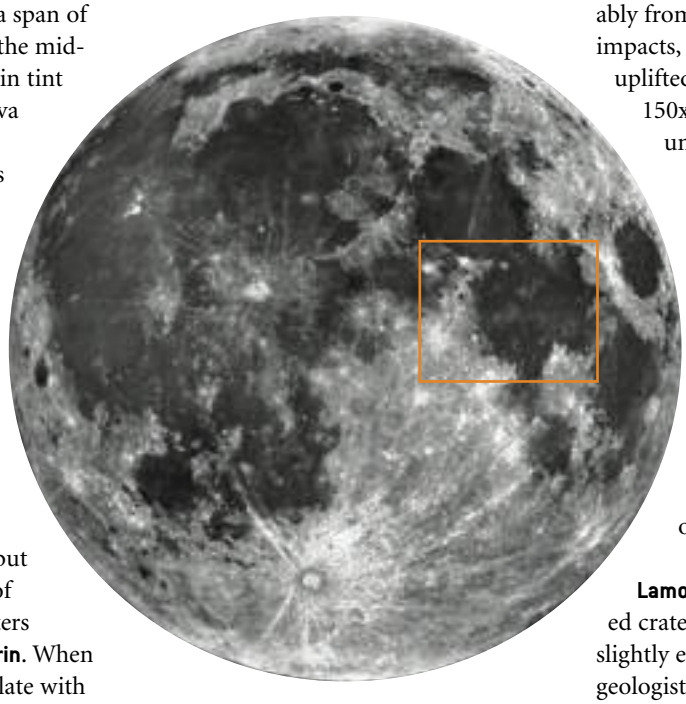
Touchdown at Tranquillity

Mare Tranquillitatis will live forever in the annals of exploration, thanks to Apollo 11, which made the first manned lunar landing on its southwestern surface in July 1969. However, to most backyard lunar observers, Tranquillitatis is one of the duller maria to view, with less topography (and interest) than others. Mare Tranquillitatis is flat because the basin it fills is old. Although its age is not known precisely, the Tranquillitatis basin is older than Serenitatis to the north (3.87 billion years) and Nectaris to the south (3.92 billion years). The asteroid that created it struck at a time when the Moon's crust was thinner and less rigid than it is today.

The sheets of basaltic lava that filled the basin were thin, accumulating a total depth of half a mile or so during a span of several hundred million years. In the middle of the mare, a distinct change in tint marks the contact between two lava flows; the darker tint represents older lava, about 3.68 billion years old versus 3.53 billion years for the younger lava. This contrast can be seen with the naked eye when the Sun angle is high.

Tranquillity Base, where Apollo 11's astronauts landed, lies on the southern part of the mare, near the impact crater **Moltke** (4 miles wide), which is surrounded by a white halo of ejecta. No easily visible landmark stands close to Tranquillity Base, but if seeing allows, look for the trio of small (1- to 2-mile-diameter) craters named **Armstrong**, **Collins**, and **Aldrin**. When you locate them, carefully triangulate with Moltke to identify the smooth patch of mare chosen for the landing site.

Rocks brought back by the Apollo 11 astronauts sampled two lava flows, one dated at 3.84 billion years old and the other 3.57 billion. The different ages show the volcanic process that filled the Tranquillitatis basin took at least 270 million years. Scientists think these rocks were excavated by the impact that made the 200-yard-diameter West crater (which is too small to be seen in the image). It lies a quarter-mile east of the landing site and dates to about 100 million years ago. The nearby craters **Sabine** (19 miles) and **Ritter** (19 miles) resemble volcanic calderas, but they actually mark a double impact, probably from a binary asteroid. After the impacts, the centers of the craters were uplifted. With a magnification between 150x and 300x, you can examine uneven bumps on their floors.



MARE TRANQUILLITATIS will always be famous as the site of the first manned lunar landing. This image appears "naked eye," with north at the top. LICK OBSERVATORY

Close by lie other rilles: the **Rimae Hypatia** and the group of small rilles lying between the craters Ritter and **Dionysius** (11 miles). These, and other craters that parallel the mare shoreline, reflect a downward movement of the mare surface as the basin bottom settled. The cracks mark where sheets of brittle lava broke under their own weight as they flexed.

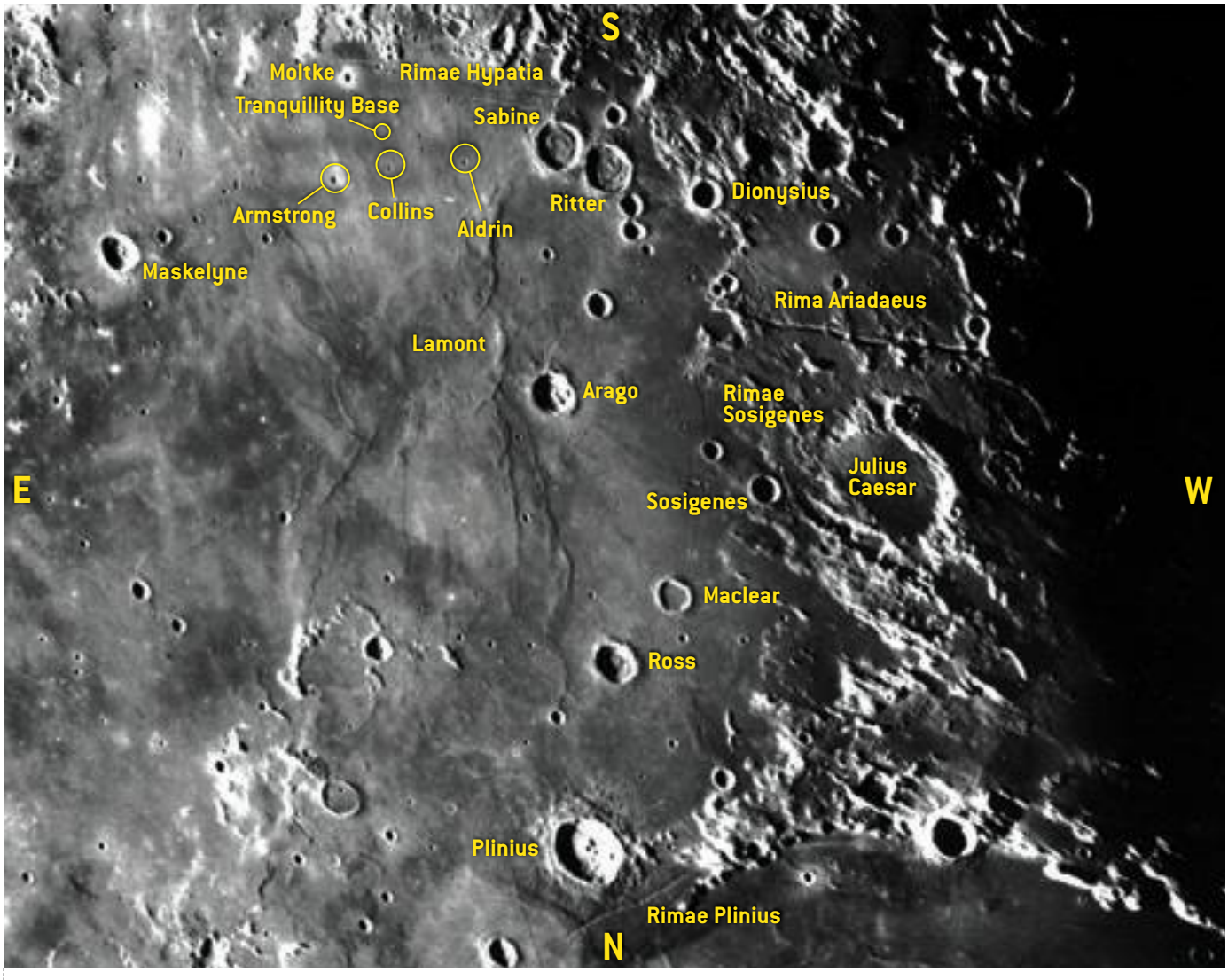
The round, flat feature named **Lamont** (47 miles) is almost an inverted crater. Noting that Lamont shows a slightly enhanced gravitational pull, lunar geologists propose it's an old impact crater that was flooded by lava and almost obliterated. The feature became "elevated" when the lava's weight depressed the basin floor around it, but not Lamont itself. The

/// BEST DATES TO OBSERVE

Lunar sunrise and sunset are the best times to view the Moon because shadow detail is greatest then. The best dates to observe Mare Tranquillitatis for the next three months are listed below.

Lunar sunrise
July 22–24, Aug. 20–22, Sept. 19–20

Lunar sunset
July 6–7, Aug. 4–6, Sept. 3–4



MARE TRANQUILLITATIS, shown here with south at top (matching the view through most telescopes), is a very old, lava-filled impact basin that has been modified by later events. This is plate D-9 from the *Consolidated Lunar Atlas*. LUNAR AND PLANETARY LABORATORY

radial pattern of wrinkle ridges you can observe reflects the subsidence.

The sculpture of the hills around Dionysius comes from the Imbrium basin to the northwest. Debris shooting from the Imbrium impact site on low trajectories scoured the terrain deeply. The 2- to 3-mile-wide **Rima Ariadaeus**, however, cuts across the Imbrian sculpture at an angle. If the rille was produced by a basin impact, as geologists think likely, then the yet-unidentified basin lies near the center of Oceanus Procellarum, which was filled by lava many eons ago. The rille's gentle relief (a few hundred yards deep) is easily visible under grazing sunlight, and the offsets in its path hint that the rille is a fault, and therefore older than the linear scars carved into the hills around it.

The ancient crater **Julius Caesar** (56 miles) has been heavily reshaped by Imbrian ejecta (the lighter material in the crater's southern half) and by mare flooding. East of Julius Caesar, the crater **Sosigenes** (11 miles) lent its name to a set of rilles resembling off-road tire tracks. They were caused when the mare lava sheets settled and fractured.

At the northern end of the rilles lie two smaller craters, **Maclear** (12 miles) and **Ross** (16 miles), which reflect freaks of positioning. Because the Maclear impact predates lava pouring in, only the upper part of its walls survived the subsequent flooding. Ross, however, exists on a higher part of the basin floor, so it was less deeply flooded with lava. Its elongated shape also suggests the impact was oblique.

The large crater **Plinius** (27 miles) postdates the mare, and the impact that formed it flung ejecta across the **Rimae Plinius** to the north, partly burying the nearest rilles. Like the rilles along the Tranquillitatis shore, these are a few miles wide and a few hundred feet deep.

Observing this region with the Sun at a low angle reveals many wrinkle ridges. As Full Moon approaches, however, return here for a look at mare tints. Dark lava can fool you as it once fooled Moon scientists. Before the Apollo landings, scientists thought lava grew lighter in color with age. More often than not, however, the opposite is true.

If unraveling the Moon's history once seemed easy, experience shows it's not. And few puzzles are trickier than this flat, seemingly boring mare where human beings first touched an alien world.

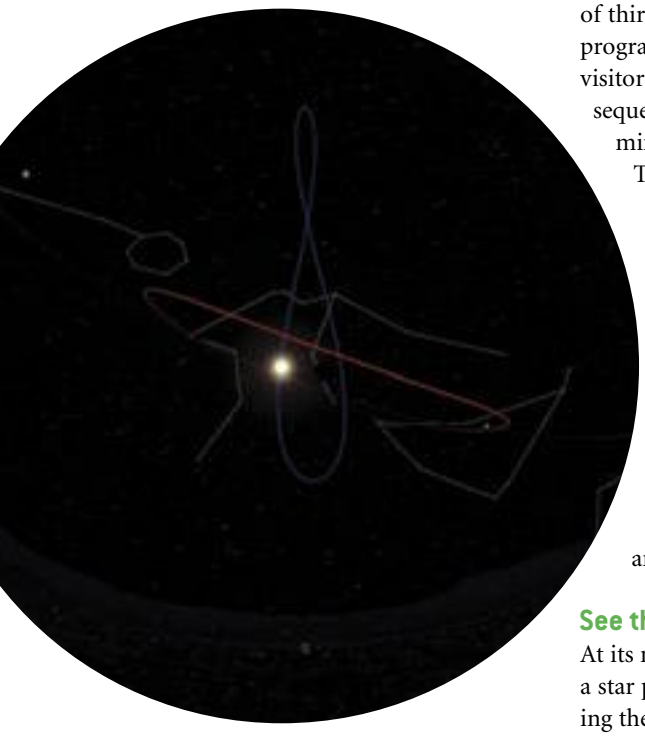
Robert Burnham, *a senior editor of* Astronomy, *is the author of the new* Exploring the Starry Sky *(Cambridge University Press).*

EDUCATION

Today's sky theaters serve a valuable purpose, introducing millions of visitors to the wonders of astronomy each year. /// BY MICHAEL E. BAKICH

A visit to the planetarium

You enter a round room. Overhead, the ceiling is a large half-sphere lit from its bottom edge. As you ease into a comfortable, slightly inclined theater chair, random words from several nearby conversations become audible. Your attention is drawn to a strange, bug-eyed machine in the center of the room. Then — ever so slowly — the lights dim; but they're not just dimming, they're changing color too. Within 30 seconds, the domed ceiling is a pleasant shade of blue. The chatter you heard earlier is quieter but resounds with anticipation. Everyone seems excited. Then the blue light begins to fade and — look there!— is that a star? Yes, and another, and another, and more until the entire ceiling — no, *sky* — is filled with twinkling lights. There must be thousands of them. What is this place? Did they open the dome and shade the daylight so we could see the stars? Suddenly, a voice from among the stars announces, "Welcome to the planetarium."



THE STARS AND CONSTELLATIONS come out to play when the lights go down at a planetarium show. Special effects help demonstrate the dynamics of celestial events. SPITZ, INC.

Before I came to *Astronomy*, I worked in eight different planetaria during a span of thirty years. I presented thousands of programs to hundreds of thousands of visitors, and the reaction to this opening sequence — both the audience's and mine — was always the same: Wow!

The planetarium is an example (perhaps the first example) of virtual reality. When darkness falls within the star theater, you're no longer in Chicago, El Paso, Salt Lake City, or Miami. Instead, you're on an alien planet, in a futuristic craft hurtling through space, whizzing past a massive star on the brink of becoming a supernova, or in a country field where there are no clouds, no city lights, and nothing but stars overhead.

See these seven stars?

At its most basic, a planetarium consists of a star projector, a domed ceiling representing the sky, a lecturer, and an audience. For decades after the first planetaria were constructed in the 1920s, basic sky lectures were the only astronomy programs presented, and those lectures almost always started with the identification of the seven stars of the Big Dipper. Sometime in the early 1950s, however, a lecturer brought a slide projector into a planetarium, and the illustrated talk was born. From that humble start, technical innovations have multiplied under the dome.

THE ADLER PLANETARIUM AND ASTRONOMY MUSEUM on Chicago's lakefront brings the boundless universe into the urban confines of light-saturated Chicago. ADLER PLANETARIUM

Tape-recorded narration allowed the same program to be given many times. Groups of slide projectors ganged together projected "panoramas" that transported visitors to alien landscapes, inside spacecraft, or to the centers of brilliantly lit cities. Pre-recorded and original music added to the drama of programs. Computers relieved console operators of the burden of manually synchronizing visual effects to the soundtrack. Lasers added a sharp, new look to visual effects and ushered in "light shows" offered solely as entertainment. Today, video projection introduces a new level of complexity and excitement under the dome as real, moving images and imaginative animations help explain the mysteries of our universe.

THE GATES PLANETARIUM inside the Denver Museum of Nature and Science offers visitors an astronaut's view of Earth. Notice the vivid Milky Way in the lower part of the dome. SPITZ, INC.

The purpose of the planetarium, however, remains the same after all these years. Behind all the facts, figures, beautiful stars, and awe-inspiring celestial images lies the desire to introduce the wonder of astronomy to the world. This goal is certainly lofty, but the planetarians I spoke with see it as attainable — and they're approaching it one group of visitors at a time. The ultimate question, therefore, is: How well is the planetarium field doing?

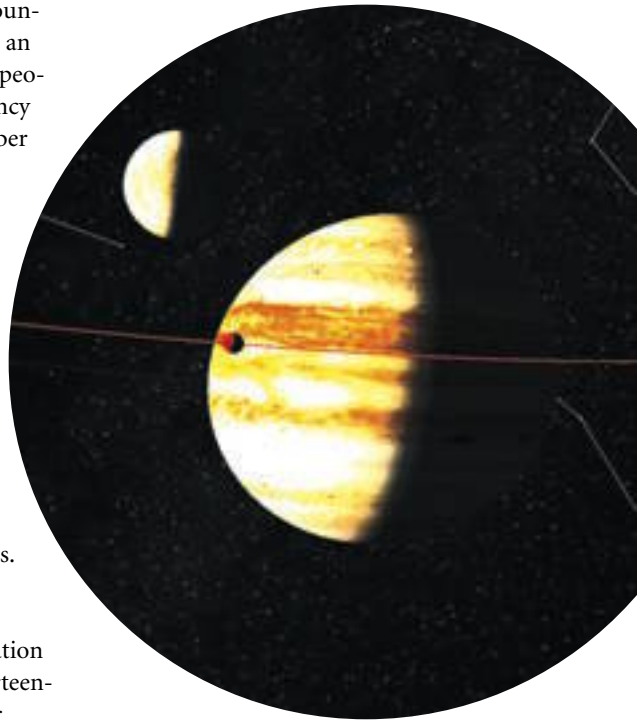
Numbers don't lie

Mark Petersen, founder of Loch Ness Productions — a supplier of programs and music to the planetarium field — compiles worldwide planetarium attendance data. In 2003, 331 of the 1,509 United States planetaria (22 percent) and 147 of the rest of the world's 1,501 planetaria (10 percent) responded to an attendance survey he sent out. From the numbers submitted, Petersen made a carefully thought-out estimate of planetarium attendance in the United States and worldwide.

Slightly more than 24 million visitors enjoyed a planetarium show in the United States in 2003. Attendance in other countries reached 69.5 million visitors, for an impressive total of almost 94 million people worldwide. The seeming discrepancy in attendance for a nearly equal number of planetaria in the United States and abroad is accounted for by the fact that more large planetaria exist in other countries. Exactly 155 stateside planetaria have domes at least 40 feet (12 meters) in diameter. 356 planetaria outside the United States — nearly one-quarter — have domes that size or larger. And when only the biggest planetaria are counted, 75 of the world's 86 domes with diameters larger than 70 feet (21m) reside outside the United States.

"Edutainment"

Scientific discovery and space exploration fuel planetarium attendance. The thirteen-year span (1977–1989) of the Voyager spacecraft encounters with the giant outer planets of our solar system was a boom time for planetaria. Celestial events, such as eclipses, also can spike attendance. "The



VISITORS CAN WITNESS the orbit of Jupiter and its moons set against a backdrop of constellations when they sit down to enjoy a show at a planetarium. SPITZ, INC.

ALL EYES ARE ON THE SKY at the Adler Planetarium and Astronomy Museum as visitors sit back with their eyes wide open. You almost can hear the collective "Wow!" from the crowd. ADLER PLANETARIUM

THE ELECTRIC SKY THEATER offered by Spitz, Inc., of Chadds Ford, Pennsylvania, uses state-of-the-art technology to immerse visitors in scenes from Earth or space. SPITZ, INC.

1990s were a golden time for such events," states Ray Shubinski, director of the newly constructed East Kentucky Science Center in Prestonsburg, Kentucky. "An annular eclipse occurred that was centered on the United States, Comet Shoemaker-Levy 9 hit Jupiter, several terrific meteor showers took place under moonless skies, and comets Hyakutake and Hale-Bopp became brilliant nighttime visitors."

In addition to general public visitation, school groups contribute to planetarium attendance in a large way. Many small planetaria present no public programs at all, relying totally on their relationships with schools to remain viable. "Our mission is to serve schools, first and foremost," says Cory Stone, assistant director of the Gene Roddenberry Planetarium in El Paso, Texas. "We do occasional public programs, mainly during the summer, but our bread and butter is school groups."

Earth's close approach to Mars in 2003 and the subsequent martian rover missions of Spirit and Opportunity get credit for the recent upsurge in planetarium attendance. Can future events be counted on for even greater attendance? Shubinski thinks so: "If President Bush's initiatives to the Moon and Mars become reality, science education will become more of a priority. If that happens, I predict planetarium attendance will reach an all-time high, especially among school groups."

Most planetarians try to strike a balance between education and entertainment, which contributes to the popularity of planetarium shows. It's difficult to get the mix just right, but planetarians accomplish it more often than not. One advantage is the subject matter; the astronomy that underlies most planetarium programs has an almost universal appeal. The environment inside a dome theater and the compelling shows combine for an inspirational and thrilling experience.

Star hustlers

Thirty-one percent of all planetaria have a dome 20 feet (6m) or less in diameter. Many of these (especially in the United States) exist in schools or museum facilities. Within these small planetaria, as well as in many medium-size sites, a staff of one is the rule rather than the exception. Who is this person? Certainly a love of astronomy is high on the list of attributes, but equal to that is a desire to share that love with others.

My wife Holley, no stranger to sky shows, once told me most planetarians she's met seem to be one part Einstein, one part Edison, and one part P. T. Barnum. This wonderful description succinctly summarizes a planetarian's scientific and

Michael E. Bakich *is an associate editor of* Astronomy *and a former planetarian.*

/// A TALE OF TWO CITIES

Charleston, West Virginia

For several decades, the tiny planetarium at the Sunrise Museum in Charleston, West Virginia, catered mainly to school groups and weekend public visitors. The peak annual attendance for the 24-foot dome was 24,000 people. Nearly ten years ago, plans were laid for a new museum and planetarium, and on July 13, 2003, those plans became reality when the new museum opened. In its first six months of operation, the Electric Sky Theater in the Clay Center for the Arts and Sciences has annihilated the record attendance of the old facility. In only half a year, more than 76,000 satisfied visitors have seen all-dome films and planetarium shows — and that in a city with a population of 55,000.

"Visitor reaction couldn't be more positive," states Rosanna McNeil, director of marketing for the planetarium. "It ranges from 'I can't believe this is here' to 'We've needed something like this for a long time.' We couldn't be happier with the way things worked out."

Kansas City, Missouri

Not all planetarium-related stories have happy endings. Consider the well-documented case of Science City in Kansas City, Missouri. As a major part of a $240 million science center that opened in late 1999, the planetarium was to be a real showpiece. Then, inexplicably, the decision was made to attempt to operate the planetarium without a director or full-time staff. The result: total failure due to lack of creative or timely programming. As of this writing, the planetarium is slated to be gutted and turned into an entryway for the science center, although a group of concerned citizens, led by members of the Astronomical Society of Kansas City, is working to have this decision reversed. If they don't succeed, Kansas Citians will be the only occupants of a major U.S. city without a large public planetarium.

THE "MARS ENCOUNTER" EXHIBIT at the Chabot Space and Science Center in Oakland, California, puts the dynamic universe in the palms of visitors' hands. CHABOT/STEVEN DOS REMEDIOS

BUG-EYED STAR PROJECTORS such as this one at Chicago's Adler Planetarium and Astronomy Museum are the heart and soul of planetaria. ADLER PLANETARIUM

technical expertise, along with his or her enthusiasm for spreading the word about astronomy. "It isn't enough just to be passionate," says Mike Murray, program manager of the Hansen Star Theater in Salt Lake City, Utah. "You also need an experienced sense of showmanship.

To find out more about the ever-evolving planetarium field, I approached a group of these star hustlers and asked them some questions. The responses resound with the intelligence, enthusiasm, and optimism found so commonly among local planetarians.

What excites you most about the planetarium?

I still get excited when I show someone their first view of Saturn and get an 'Oh, wow!' reaction. And, because I've been in the planetarium field for 35 years, with certain people, I've been able to see the initial spark turn into a lifetime interest in astronomy. I'm not saying these folks are astronomers, but they've incorporated a love and understanding of astronomy into their everyday lives. — Dave Batch

Director of Abrams Planetarium at Michigan State University in East Lansing, Michigan

Having the light bulbs turn on when the audience gets it. — Cory Stone

What's the current state of the planetarium?

We're at a crossroads. The old-fashioned way of producing programs — by piecing together images from slides, videos, and special effects — required planetarians to have a huge set of skills. Unfortunately, a lot of this equipment isn't being supported anymore. The new format is digital, all-dome projection, but moving in that direction is a slow process because it's so expensive. The field is in a state of flux. — Cory Stone

The field is more active than in recent years. More construction of star theaters is going on in parts of the country. The exciting undercurrent of all-dome digital projection is fostering new community interest.

— John Elvert

President of the International Planetarium Society and director of the Irene Pennington Planetarium in Baton Rouge, Louisiana

What draws so many people to planetarium shows?

Everyone who visits a planetarium is interested in astronomy at some level. It's our job to find that level. — Dave Batch

The planetarium field is now old enough that many of our visitors have a historical perspective — they remember a wonderful visit when they were 8 years old, and they've come back to rekindle those memories. — John Elvert

The future

My final question to these astronomy showmen dealt with where the planetarium field is headed. Because it involved speculation, this question was more difficult to answer than the others.

When the smoke clears and the last slide projector dies, you'll still find planetaria. The mysterious nature of planetaria will be a draw one hundred years from now. — Cory Stone

Economics may not allow [many small planetaria]. As long as I've been a planetarian, our field has fluctuated like a sine wave — but it will never go away. The way shows are scripted and designed is evolving. We're becoming more poetic and philosophical in our approach and starting to answer the question 'why' along with providing facts. — Mike Murray

The future means learning to use the new technology. After planetaria (including portables) incorporate all-dome digital video, we may not be ready for another change for a while. — John Elvert

Digital projection and Hollywood-style special effects are fine as far as they go. However, re-creating the night sky drove the beginning of the planetarium community, and people flocked in. I think a high-quality, optically projected sky encompasses a universe that we're fast losing from Earth's surface. If light pollution keeps growing, the only place to see the stars will be planetaria, and they may turn into a whole new entity — 'museums of the sky.' — Ray Shubinski

Batch sees a melding of the traditional way of doing things with all-dome digital projection. On a philosophical note, he added, "The need will always exist for people to be in touch with their corner of the universe. That's where we come in."

When optical and mechanical excellence are paramount, Meade's 10-inch LX200GPS-SMT sets a high standard. /// BY STEVE EDBERG

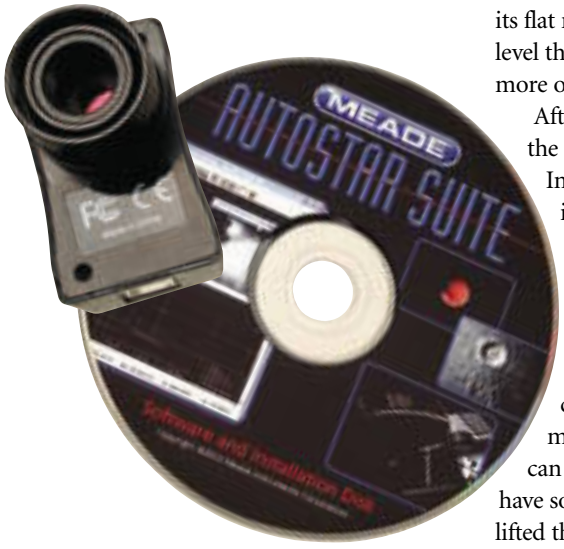
Star power

Meade's 10-inch LX200GPS-SMT with Autostar Suite hurried along something that's been a long time coming in my life: I've finally become a cyberastronomer. The Autostar Suite of software and hardware is so easy to use that I was driving the telescope with a cranky old computer and taking images

with Meade's Lunar Planetary Imager (LPI) camera on the first night I tried it.

That's not to say I didn't do some daytime experimenting first (as Meade recommends) and that I didn't have problems (sometimes computers just don't behave quite the way they are expected to by instruction-manual writers). But I managed to get it all working with minimal frustration. Watch out, sky. Here I come!

Meade Instruments's LX200GPS-SMT telescope line builds on their earlier LX200 and LX200GPS models. Besides upgrading the mounts and hand control, the package now includes the Autostar Suite with a CCD camera for lunar and planetary imaging. You can do so much with this system. It's hard to know where to begin, so I thought I'd start from the ground up.



MEADE'S LUNAR PLANETARY IMAGER (LPI) will quickly introduce you to the joys of CCD imaging. Meade also includes software that controls the CCD camera and helps you process the images you obtain. *ASTRONOMY*: JAMES FORBES

The foundation

The package includes Meade's variable-height field tripod, a sturdy support for the telescope. At 20 pounds, it's not too hard to maneuver into position, and a spirit level on its flat mounting surface will help you easily level the telescope (if you want to bother — more on that later).

After some minimal assembly (attaching the finder scope, inserting the Zero Image-Shift Microfocuser, and installing eight D-cell batteries for power), the fork-mounted telescope can be placed on the tripod. At 62 pounds, this 10-inch Schmidt-Cassegrain telescope and fork is about as hefty as a small bag of concrete but much bulkier and harder to maneuver. One large, strong person can place it on the tripod, but it's safer to have someone around to help. Once you've lifted the scope, the hardest part is centering the base of the drive over the center bolt of the tripod.

If you like leaving your telescope assembled and need to move it from indoors to outdoors and back, you probably will want wheels for the tripod. For observing, I roll my telescope onto my gently sloped driveway. After locking and blocking the wheels, I am ready to go.

Let the fun begin

I flipped a switch and turned on the telescope drive. I read the safety message and pressed the indicated key, and then the Autostar asked what type of alignment to use. Naturally enough, I chose GPS, the simplest of the options. GPS stands for "Global Positioning System," a constellation of orbiting satellites that transmits signals GPS receivers can convert to the observer's latitude, longitude, altitude, and Universal Time. This telescope knows exactly where it is and what time it is when the GPS system is in use.

The telescope went through the full alignment procedure, including finding magnetic north with its built-in compass and finding level automatically (remember, I was set up on my sloping driveway). When the hand control displayed "ready," I started using its catalogs of stars, deep-sky objects, and planets to navigate the sky. The go-to drive found my selection every time — usually with the object within the central one-half radius of the field of view of the included 26mm Super Plössl eyepiece. This was really fun! The telescope's images were as good as the mediocre seeing permitted me to discern, and I expect them to be fine in steady seeing.

I use this particular telescope for serious work, so that same evening, I took it off the tripod and moved it onto the permanent pier and wedge in my backyard. After tracing through the menu tree (illustrated in the instruction manual), I easily switched the

Steve Edberg *bought his first telescope in the 1960s. It moved by hand-turning a knob. He's thrilled to finally be catching up with recent breakthroughs in electronics and telescope control.*

THE LX200GPS-SMT telescope by Meade Instruments Corp. is a complete, high-quality system. *ASTRONOMY*: JAMES FORBES

MIRROR SHIFT IS NO PROBLEM when you use the included Zero Image-Shift Microfocuser, seen here between the telescope's body and the star diagonal, which holds the eyepiece. *ASTRONOMY:* JAMES FORBES

telescope mount from altitude-azimuth mode to equatorial mode. I followed the directions for coarsely polar aligning the telescope. After I finished this step, the computer acquired the time from the GPS system and had itself operating correctly in equatorial mode. Note: If you're a bit sloppy about your initial polar alignment, the centering of targets won't be as good as you hope. Don't blame that on the instrument.

THE AUTOSTAR II CONTROLLER, which possesses the full power of a computerized, go-to drive system, fits comfortably in your hand. *ASTRONOMY:* JAMES FORBES

Imaging with the LPI

A few nights later, I brought out the computer and LPI camera together, and I was even sloppier with the initial alignment (because I haven't set up the system in its "observatory" mode yet — that will happen when I permanently mount the scope on a pier). Still, my targets were always in the field of view of a low-power eyepiece and appeared rather consistently at one edge. I then manually centered each object, and the LPI took over.

I strongly recommend getting a flip mirror assembly for centering the object in the camera. The LPI's sensor chip is quite small, so centering is critical and much easier by flipping a mirror rather than pulling out the eyepiece and putting in the camera. Focusing is more assured and quicker with this method, especially if you parfocalize the camera and eyepiece. Because the two items are parfocal, they can be switched with no additional focusing necessary. A ring is supplied for this purpose. You may need to make or buy an extension tube to hold your eyepiece at the parfocal position in a flip mirror assembly. To make your own, purchase 1¼" chrome plumbing extension tubing and line the smaller section with black velvet on the inside. You may have to shorten the tube first with a hacksaw. Be sure to file the edges until they're smooth.

When you start using the camera, whether during daytime as Meade recommends or with the telescope at night (try the Moon first), don't forget to adjust the exposure duration. Initially, you will probably greatly overexpose a sunlit scene. This won't damage the camera; however, you will wonder what's wrong when you see a bright white image on your computer screen.

My first nighttime attempt at imaging was to observe the Moon as it occulted the double star Porrima (Gamma [γ] Virginis). The LPI performed well, but the occultation was poorly observed due to abominable seeing. However, I was treated to an impressive demonstration of the LX200's drive system. After Porrima disappeared, I simply let the telescope track at the sidereal rate to see how close Porrima would be to its disappearance position on the camera's sensor when it reappeared. Seventy minutes later, Porrima was still in the field of view, having drifted perhaps one-third of the camera's narrower, vertical dimension. I am surprised that the polar alignment of the wedge is that good (no doubt helped by Meade's alignment procedure, but I did no drift aligning) and delighted to see the mount's clock drive is so consistent. Drift aligning, training the Smart Drive, and using the drive's Periodic Error Correction will reduce the minimal drift I observed even further. The LPI even can be used as an auto-guider, if desired.

The LPI camera is surprisingly small, only about the size of two fingers. It comes with a short USB cable that forces the computer and telescope close together. I recommend you purchase either a longer one or an extension.

The beauty of the Autostar Suite is that it eases you into using the computer and imager. I found the instructions to be clear and straightforward. With the Starmap, LPI control, and image-processing software included in the suite, the whole package serves as a trainer for more advanced imaging cameras. I expect to get well acquainted with the LPI and then switch to another CCD camera for deep-sky imaging. While the details of camera operation will differ, the familiarity with camera operations in general should make the transition smooth.

Autostar features

The LX200GPS-SMT is a great overall system, and I had few problems. Yes, the software wasn't quite friendly enough to allow me to work without the manual. When I learn all the commands, that will change. At one point during an observing session, the program prevented me from selecting objects that were high in the sky but not projected on the computer screen, and I couldn't figure out how to use the computer to move the telescope to the new object. Again, these are small problems that will work out with more practice.

Operating the Autostar hand control also gets easier the longer you use it. I'm not a fan of the soft rubber buttons so common on remote controls nowadays, so be careful pushing the Autostar's buttons, especially when you're wearing gloves. Until you really learn the Autostar, you may find it handy to have a copy of the menu tree (which is printed in the manual) close by. Many options are available to choose from, and some are buried rather deep in the program. Celestial objects ranging from constellations and lunar features to individual stars and deep-sky objects can be selected at will, and you even can add your own terrestrial (and celestial) landmarks or follow man-made satellites.

The hand control computes celestial events like Sun and Moon rise/transit/set and eclipses, lunar phases, meteor showers, equinoxes and solstices, and even minima of the variable star Algol. It also offers a glossary of astronomical terms. I tried the "Tonight's Best" tour and found it was a nice selection of objects. You also can try the "How Far is Far?" tour or one of the others built into the Autostar Suite software. The manual shows how to build and program your own tours, and other tours can be downloaded from the Internet.

The *Utilities* selection of the Autostar hand control is useful for making adjustments and calculations during an observing session. You can set a timer and alarm and even make eyepiece calculations with it. You also can adjust the display's brightness and contrast, check the temperature, park the telescope, or place it in power-saving mode.

The *Setup* menu controls various telescope operations like anti-backlash, Periodic Error Correction in both axes, observing sites, computer downloads, and a variety of other functions.

Meade has really thought through focusing issues and included a microfocuser and mirror lock with this scope. These features prevent image shift from occurring during fine focusing. You'll find this especially valuable for CCD imaging.

An owner's-manual illustration shows the Autostar II holder attached to one of the handles built onto the fork arms. It's great to have a place to put the hand control, but don't attach the holder before the telescope is assembled and mounted or the holder interferes with using the handle. I temporarily mounted it on the tube handle instead, but that positioned the hand control on its side.

THE MAIN PANEL of the LX200GPS-SMT has inputs for the hand controller, an external computer, AC power, and more. *ASTRONOMY:* JAMES FORBES

The bottom line

Meade's 10-inch LX200GPS-SMT with Autostar Suite will give you (and me) many nights of observing pleasure. This telescope offers high-quality optical performance, superb mechanical craftsmanship, accurate object location and tracking, and a fully functional CCD imaging suite. It will allow you to explore the universe easily, as shallowly or as deeply as your sky permits.

THE OPTICAL PATH of the LX200GPS-SMT sends light through a corrector plate onto a spherical primary mirror, where it's reflected to a secondary mirror (attached to the corrector plate). The secondary mirror reflects the light through a central hole in the primary mirror and into the eyepiece. *ASTRONOMY:* JAMES FORBES

/// PRODUCT SPECIFICATIONS

Meade 10-inch LX200GPS-SMT with Autostar Suite

Dimensions:
12" by 20" by 31"

Eyepiece:
Series 4000 26mm Super Plössl

Finder scope:
8x50

Accessories:
- AutoStar II control system
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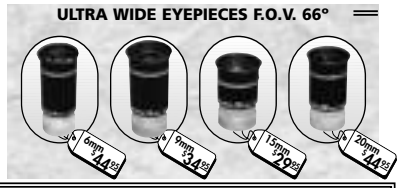

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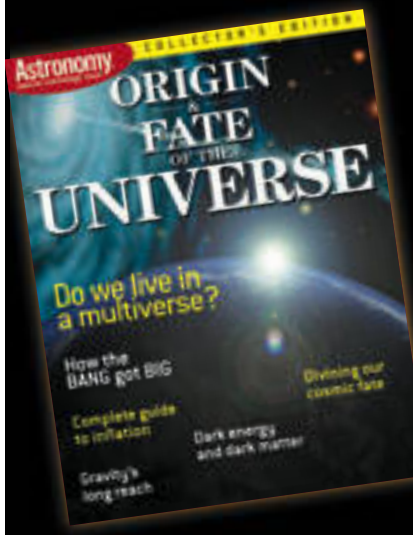
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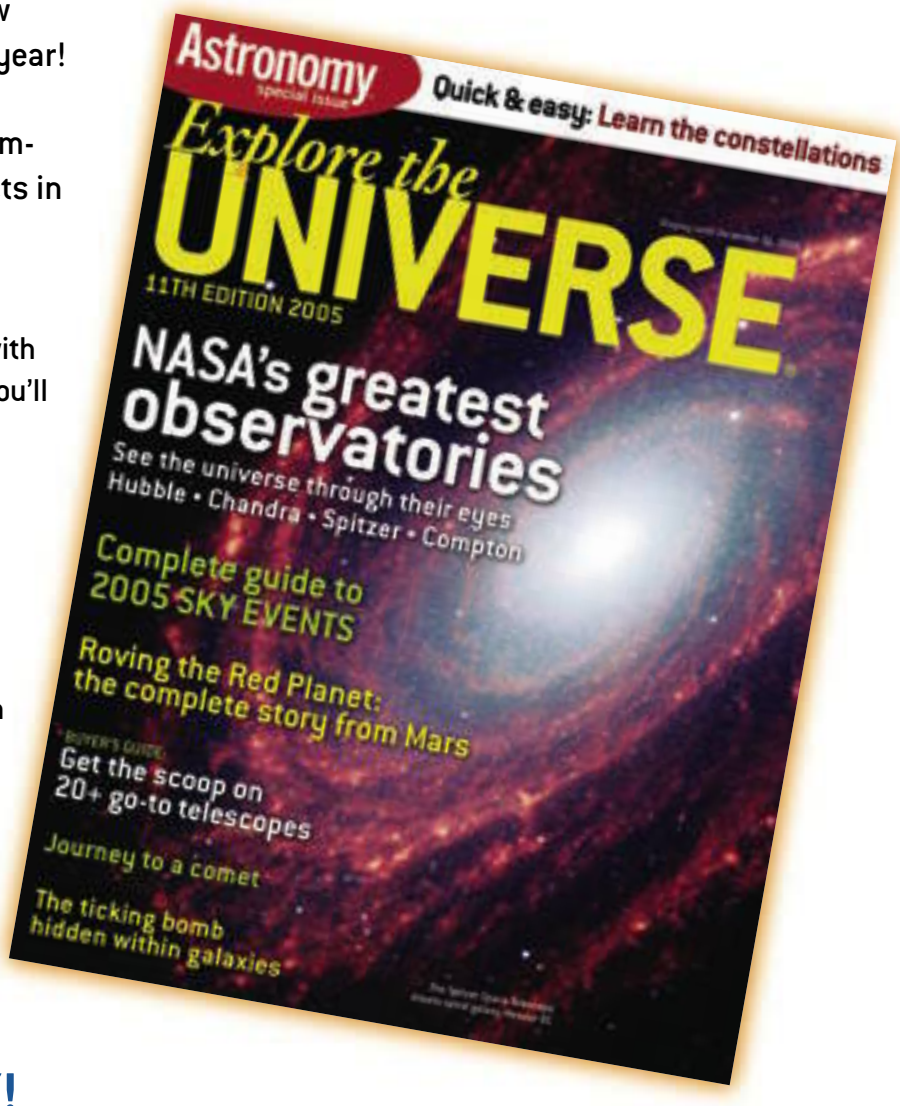
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A Baedeker for Moon buffs

The Modern Moon: A Personal View
Charles A. Wood, 209 pages, Sky Publishing Corp., Cambridge, Massachusetts, 2003; ISBN 0–933346–99–9; hardcover, $44.95.

Although you can't yet book passage to it, you *can* visit another world. Earth's Moon is unique in the night sky. It's a real place with strange landforms and unusual features — all visible through the most inexpensive of telescopes. Casual observers often make the Moon their first target, and many become hooked on it forever.

They now have a field guide to their new world. Chuck Wood has written an informative book on the most significant and important lunar features. *The Modern Moon* also tells the story of lunar science, from its days struggling with crackpot hypotheses to the central role it plays today in planetary science. Reading this book will reward every lunar observer with a better appreciation of the Moon's surface, its history and evolution, and how we came to comprehend it.

The book is organized in chapters that cover specific geographic regions of the Moon. After a couple of introductory chapters that describe the Moon, how to observe it, and the roles that cratering and volcanism have played in lunar history, Wood takes the reader on a guided tour of the nearside, describing the major basins and maria. Each chapter is accompanied by many clear black-and-white illustrations and photos.

Along the way, Wood describes scientific controversies that have raged over the origin of this or that feature. Reading the book provides a trip through space and time, as the complicated story of the Moon is gradually revealed. Wood's commentaries on debates among lunar scientists are enjoyable for those interested in the history of science. I found the "mug shots" of lunar scientists (many of them new to me) particularly delightful.

The book is subtitled "A Personal View," and many of Wood's preferences emerge. One of these is his belief in the existence of a "Procellarum [a.k.a. Gargantuan] basin," a postulated megabasin encompassing most of the western maria on the nearside. Wood expresses astonishment that more lunar scientists don't accept this idea. One explanation may be that Procellarum would be the only basin in the solar system with an interior topography higher than the elevation of its putative rim! The outline of the Procellarum rings is much less obvious on the new global topographic map produced by Clementine than it was in earlier maps made using telescopic images.

Differences of opinion aside, I found few errors of fact. In the story of Apollo 16, Dick Eggleton (U.S. Geological Survey) did not advocate a volcanic origin for the Descartes material. In fact, Eggleton took considerable flack from colleagues for saying that the Descartes material was Imbrium ejecta, so he hardly deserves being lumped with the volcanic ideologues! Discussing the south pole, Wood refers to a peak that he says the Clementine team named "Mt. Clementine." But as an accessory before, during, and after the fact, I know of no such name.

Despite thirty years of study, I learn new things about the Moon every day, and I learned new things from this book. *The Modern Moon* is a wonderful guide to our nearest planetary neighbor and is a must-own for any serious lunar observer.

— PAUL SPUDIS *studies the Moon and planets from the Applied Physics Laboratory of Johns Hopkins University.*

Sky Vistas
Craig Crossen and Gerald Rhemann, 282 pages, Springer-Verlag, New York, 2004; ISBN 3–211–00851–7; hardcover, $69.95.

Astronomy writer Crossen and astrophotographer Rhemann pool talents to give readers the low-power universe — the sky as seen with binoculars and rich-field telescopes. This is a practical and stunningly beautiful guide whose core is a descriptive tour of the best celestial sights: open and globular clusters, nebulae, galaxies, and large areas of sky (especially along the Milky Way). These are the "vistas" mentioned in the title. The photos, in black and white and color, are magnificent. Crossen's text goes beyond ordinary descriptions to tell the reader something about each object's nature. It's not quite eyeball-astrophysics, but it comes close.

Strange Universe
Bob Berman, 212 pages, Times Books, New York, 2003; ISBN 0–8050–7328–0; hardcover, $25.

Astronomy readers know something of Bob Berman and his strange universe. This book gathers 32 short chapters on all sorts of topics, from the physics involved in going to work to what alien life-forms might look like (and how they'd function biologically) to the truly deep weirdnesses involved in relativity and space-time. The tone, as always with Berman, is light and easy, which makes the topics seem a lot simpler than they really are. But this is an ideal way to entice — and ease — beginners to explore the profound topics astronomy deals with.

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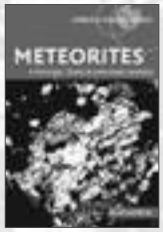

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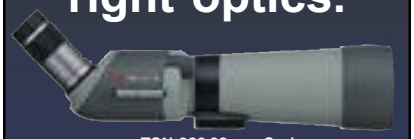

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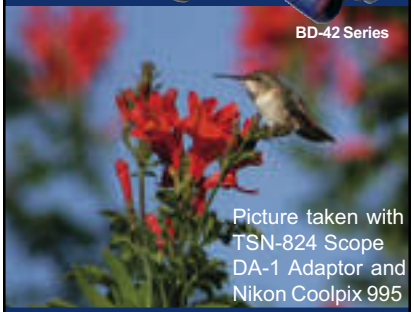

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08.12.04–08.14.04

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the Cheyenne Astronomical Society and Laramie Astronomical Society and Space Observers invite you to the 14th annual Weekend Under the Stars. Last year's event was threatened by wildfires, and the sky suffered due to smoke

STAR CLUSTERS M6 (TOP RIGHT) AND M7, located between Scorpius's stinger and Sagittarius's teapot spout, are easy, naked-eye puffs to spot and further investigate at summer star parties. TIM BARNWELL

blanketing the air. Although a blessing for those fighting the fires, rain occurred almost daily, making for even worse observing conditions.

Determined to put the unfortunate circumstances of last year behind them, the organizers are planning for a bigger and better event this year.

This year, expect lectures, vendors, workshops, prizes, games for young and old, and excellent observing. Under a dark sky at 9,100-feet (2,800 meters), some 7th-magnitude stars can be seen with the naked eye.

For more information, e-mail, casmail@bresnan.net; web site, *home.bresnan.net/~curranm*.

07.15.04–07.18.04

RocheStar Fest

Wolk Observatory, Ionia, New York. RocheStar Fest offers demonstrations, lectures, children's activities, workshops, vendors, and a catered dinner featuring a prominent speaker from the astronomical community. This is a popular gathering thanks to the clear, rural skies of upstate New York. For more information, visit *www.rochesterastronomy.org*.

07.16.04–07.18.04

Table Mountain Star Party

Table Mountain, near Ellensburg, Washington. The highlights will be dark-sky observing and lectures from prominent figures in the astronomical community. Attendance at the star party is restricted to 700 people, so register as soon as possible. For more information, visit *www.tmspa.com*.

07.16.04–07.18.04

Connecticut River Valley Astronomer's Conjunction

Northfield Mountain Recreation and Enviromental Center, Northfield, Massachusetts. The 21st annual conjunction will feature lectures,

observing, and workshops. *Astronomy* magazine contributing editor Phil Harrington is one of the meeting's coordinators and will be in attendance. For more information, visit *philharrington.net/astroconjunction.*

07.17.04

Cuyahoga Astronomical Association Annual Convention

The CAA Observatory, near the Letha House Park Barn, Chatham Township, Ohio. Although an annual gathering for the astronomical group, this event is open to the public. Besides observing, the day will feature a pot-luck dinner, contests, vendors, lectures, and workshops. For more information, contact Albert Matyas at 440.878.0278; e-mail, amatyas@wowway.com; Ken Hubal at 440.230.1836; e-mail, hubalkj@netzero.com; web site, *www.geocities.com/cuyastro*.

07.18.04–07.23.04

Nebraska Star Party

Merritt Reservoir, near Valentine, Nebraska. One of the summer's most popular star parties, the NSP is located in the heart of the sandhills of north-central Nebraska. The nearby lake and pristine beach offer great additional activities. For more information, visit *www.nebraskastarparty.org*.

08.12.04–08.14.04

Riviera Astrocamp

Torquay Boys' Grammar School, Torquay, United Kingdom. This overnight event is open to those of all ages interested in astronomy. Participants will have the opportunity to take part in a rocket launch competition. For more information, visit *torbayastro.org.uk* or *www.halien.com/swaa*.

08.13.04–08.15.04

Northwoods Starfest

Hobb's Observatory in the Beaver Creek Reserve, near Eau Claire, Wisconsin. Known for its relaxed atmosphere and dark skies, this is the 16th annual gathering at Hobb's Observatory. A 5-meter dish at the observatory will be of interest for fans of radio astronomy. For more information, contact Bert Moritz at 715.835.4034; e-mail, moritz@charter.net; web site, *www.cvastro.org*.

08.14.04–08.15.04

Toledo Astronomical Association Summer Star Party

Pioneer Scout Reservation, Pioneer, Ohio. Bringing in astronomers from throughout the Midwest, the reason for this party is to celebrate the relocation of their 25-inch scope. For more information, e-mail either Don Murad at dmurad@uoft02.utoledo.edu or Alan White at alanwhite@acsitoledo.com.

08.17.04–08.22.04

Astroblast

Oil Region Astronomical Observatory in Two Mile Run Park, near Franklin, Pennsylvania. First held in 1994, this star party is blessed with a remote dark-sky location despite its proximity to urban areas. For more information, contact John O'Hara at 814.677.3972; e-mail, astroblast@oras.org; web site, *www.oras.org*.

09.16.04–09.19.04

Illinois Dark Skies Star Party

Jim Edgar Panther Creek State Fish and Wildlife Park, near Springfield, Illinois. Cosponsored by the St. Louis Astronomical Society and the Sangamon Astronomical Society, this star party is a popular destination for observers from southern Illinois and Missouri. Outdoor activities such as hiking, horseback riding, and fishing provide something to do when not behind the eyepiece. For more information, visit *www.sas-sky.org* or *www.slasonline.org*.

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

INDEX *of* ADVERTISERS

ASM Products 106
Adorama 92, 93
Anacortes Telescope and Wild Bird 27
Analytical Scientific 107
Astro Domes 109
Astro Physics 108
Astronomical Adventures 108
Astronomics 74
Astronomy Magazine 22, 102
Astronomy Special Issue 92
Beam of Light Technologies 109
Berger Brothers Camera 107
Beta Electronics 109
Bob's Knobs 109
Bubba's Bits, Inc 106
Cambridge University Press 99
Celestron 55, 56, 61, 62
Coronado Instrument Group 29
Denkmeier Optical 109
Digitec Optical 101
Eclipse 2005 Galapagos Tour 110
Eclipse Tahiti Tour 105
Explore the Universe 95
Focus Camera 68-69
Galactica 360 109
Glatter, Howard 108
Hands on Optics 101
Ideal Astronomy 106
Into the Wind/The Kite Source 109
James Cook University 99
Jim's Mobile Industries 33
Johnsonian Designs 106
Kansas Wind Power 108
Kowa Optimed, Inc. 101
Learning Technologies, Inc. 106
Lumicon 15
Mag One Instruments 109
Marketplace Pages 106-109
Meade Dealer Pages 12-13
Meade Instruments Corp 2, 3, 7, 8, 9, 10, 11, 116
New Mexico Skies 107
Newport Glass Works 108
Novaspace 110
Observatory, Inc., The 109
Oceanside Photo & Telescope 97
Orion Telescopes & Binoculars 18-19, 115
Pixsoft 107
RITI 107
Rainbow Symphony 108
Ritz Camera Superstores 106
Rivers Camera Shop 105
SAC Imaging Systems 106
SCS Astro 108
Science Connection, Inc. 106
Scope City 100
Scope Stuff 107
ScopeTronix 31
Shutan Camera & Video 100
Sirius Observatories 108
Sky Time Inc 106
Smartcase Designs 107
Software Bisque, Inc 21
Star Hill Inn 106
Starry Night 99
Starsplitter Telescopes 106
Stellar Vision 109
Stellarvue 107
Surplus Shed 108
Swinburne University of Technology 94
T & T Binocular Mounts 107
Technical Innovations 101
Telescope Warehouse, The 106
Website Directory 110
Willmann-Bell, Inc. 108
Woodland Hills Photo Images 25
www.bigbinoculars.com 106
Yankee Robotics 109
Zero Products 109
Zerpec, Inc. 107

RESOURCES

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JUPITER'S WATER WORLDS

ARTICLES — The Galileo spacecraft's mission to Jupiter and its moons was summarized in "The long goodbye" by Michael Carroll (*Astronomy*, October 2003). The heart of the article discussed the last science of the mission, garnered during a flyby of the small moon Amalthea, and the spacecraft's fatal plunge into Jupiter. For more on the existence of Europa's ocean and the possibility of life therein, see "Diving into Europa's ocean" by Michael C. Milstein (*Astronomy*, October 1997).
WEB — The best site on the discovery of water on the icy moons of Jupiter, as well as all the findings made by the Galileo spacecraft, is *galileo.jpl.nasa.gov/*. The National Space Science Data Center's site, *nssdc.gsfc.nasa.gov/planetary/planets/jupiterpage.html*, is another excellent resource on Jupiter and its moons that covers more than the Galileo mission.

HOW EARTH GOT ITS MOON

BOOKS — A good introduction to the history of Moon-origin theories and the personalities who developed them is Dana Mackenzie's *The Big Splat* (John Wiley & Sons, New York, 2003). *The Once and Future Moon* by Paul Spudis (Smithsonian Institution Press, Washington, D.C., 1996) provides a geological history of the Moon for the general reader as well as a plea for returning to the Moon for scientific and other reasons.

For those who want to dive into more technical material, take a look at *Origin of the Earth and Moon*, edited by Robin Canup and Kevin Righter (University of Arizona Press, Tucson, 2000). It contains 29 papers on all aspects of the subject.
WEB — The first scientific compilation outlining the giant-impact theory was *Origin of the Moon*, edited by William K. Hartmann, Roger J. Phillips, and G. Jeff Taylor (Lunar and Planetary Institute, Houston, 1986). It is out of print now but available on-line at *ads.harvard.edu/books/ormo/*.

DID NASA FAKE THE MOON LANDING?

BOOKS — For a critical look at the facts of the Apollo program, read Phil Plait's *Bad Astronomy: Misconceptions and Misuses Revealed, from Astrology to the Moon Landing Hoax* (John Wiley & Sons, New York, 2002). To understand what's driving the thought processes of those who think we didn't go to the Moon, read *Why People Believe Weird Things: Pseudoscience, Superstition, and Other Confusions of Our Time* by Michael Shermer (Owl Books, New York, second edition, 2002).
WEB — A comprehensive web site that uses facts to undermine the argument that we didn't go to the Moon may be found at *www.redzero.demon.co.uk/moonhoax*. Phil Plait's Bad Astronomy site has an area devoted to the FOX-TV show at *www.badastronomy.com/bad/tv/foxapollo.html*.

TO THE COSMIC EDGE

ARTICLE — The power of Hubble's Advanced Camera for Surveys can be seen by comparing the Ultra Deep Field with the first Deep Field, taken with the Wide Field and Planetary Camera 2. Read all about the original in "Approaching the edge of space and time" by Robert Naeye (*Astronomy*, April 1996).

VISIONS OF SPACE

BOOKS — More than 200 full-color reproductions of artwork appear in *In the Stream of Stars: the Soviet–American Space Art Book* (Workman Publishing Co., New York, 1991). Planetary scientist William K. Hartmann's *Out of the Cradle* (New York, Wadsworth Publishing Co., 1984), which addresses space exploration in the 21st century, showcases paintings by Hartmann, Ron Miller, and Pamela Lee.

Imagining Space (Chronicle Books, San Francisco, 2001) by NASA chief historian Roger Launius and American University professor Howard McCurdy chronicles predictions of space exploration from 1950 through 2050. In this lavishly illustrated book, the authors explore what was envisioned and what became reality, as well as possibilities for the future.
WEB — The International Association of Astronomical Artists provides a gateway to numerous space artists' web sites at *www.iaaa.org*. The site also posts notices about upcoming art shows and provides links to related sites.

Noted astronomical artist Kim Poor operates Novaspace Gallery, one of the largest galleries of space art in the world. Located at *www.novaspace.com*, the gallery offers prints, including limited editions, and other merchandise such as calendars, posters, and screen savers on CD-ROMs.

NASA maintains a space-art page at *vesuvius.jsc.nasa.gov/er/seh/spaceart.html* that provides a collection of art documenting the development of the American space program.

TOUCHDOWN AT TRANQUILLITY

BOOKS — For a detailed, highly illustrated account of impact basins on the Moon and elsewhere, read *The Geology of Multi-Ring Impact Basins: The Moon and Other Planets* by Paul Spudis (Cambridge University Press, New York, 1993).

For observing, the lunar atlas of choice for many amateur astronomers is Antonín Rukl's *Atlas of the Moon* (Kalmbach Publishing Co., Waukesha, Wisconsin, 1993). This atlas is out of print; however, you may find used copies for sale occasionally.
WEB — For information related to scientific results obtained during the Apollo missions, visit the Lunar and Planetary Institute's web site at *www.lpi.usra.edu/expmoon/apollo_landings.html.*

Teachers can find information, resources, and lesson plans designed by NASA at *lunar.arc.nasa.gov/education/teacher*. A discussion of lunar rocks (including how institutions may request samples for public display) may be found at *www-curator.jsc.nasa.gov/curator/lunar/lunar.htm*.

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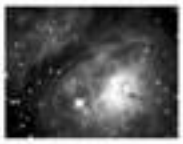

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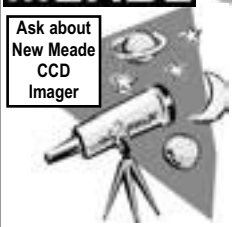

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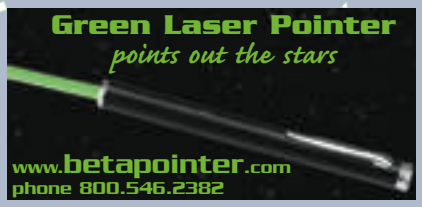
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Above, **EMISSION NEBULA NGC 6357 IN SCORPIUS** (4-inch Takahashi FSQ 106 apochromatic refractor at f/5.3, SBIG ST-10XME CCD camera, hydrogen-alpha/GB image with exposures of 120, 40, and 60 minutes, respectively) /// **DANIEL B. PHILLIPS**

A GLOWING GAS CLOUD

Emission nebula NGC 6357

This beautiful gas cloud known as NGC 6357 lies 5,500 light-years away from Earth within the boundaries of the constellation Scorpius the Scorpion. Because of its location in the plane of our Milky Way Galaxy, the entire nebula and the stars associated with it are reddened by intervening dust to such an extent that blue stars within the nebula are not evident. Analysis of the nebula's light reveals the green and blue components are dimmed by more than a factor of ten compared to the red component. Emission nebulae such as NGC 6357 also emit a large amount of hydrogen-alpha light, the same light produced by the chromosphere and prominences of our Sun.

Top left, **THE COCOON NEBULA (IC 5136)** (8-inch Takahashi Epsilon 210 Astrograph wide-field reflector at f/3, Santa Barbara Instrument Group ST-8E CCD camera, LRGB image with exposures of 30, 12, 12, and 12 minutes, respectively) /// **RICHARD JACOBS**

Top right, **NOVA SAGITTARII 2004** (12-inch Ritchey-Chrétien telescope, SBIG ST-8XE CCD camera, LRGB image with 2-minute exposures in each channel, taken with the use of a remote computer interface from New Mexico Skies Observatory near Cloudcroft, New Mexico) /// **JOHN CHUMACK**

Above, **THE FOXFUR NEBULA IN MONOCEROS (NGC 2264)** (8-inch Intes MK 69 Maksutov-Cassegrain telescope at f/6, Starlight X-Press SXV-H9 CCD camera, hydrogen-alpha/LRGB image with exposures of 60, 60, 21, 21, and 21 minutes, respectively) /// **GERALD RHEMANN**

Send your photos to: ASTRONOMY reader gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
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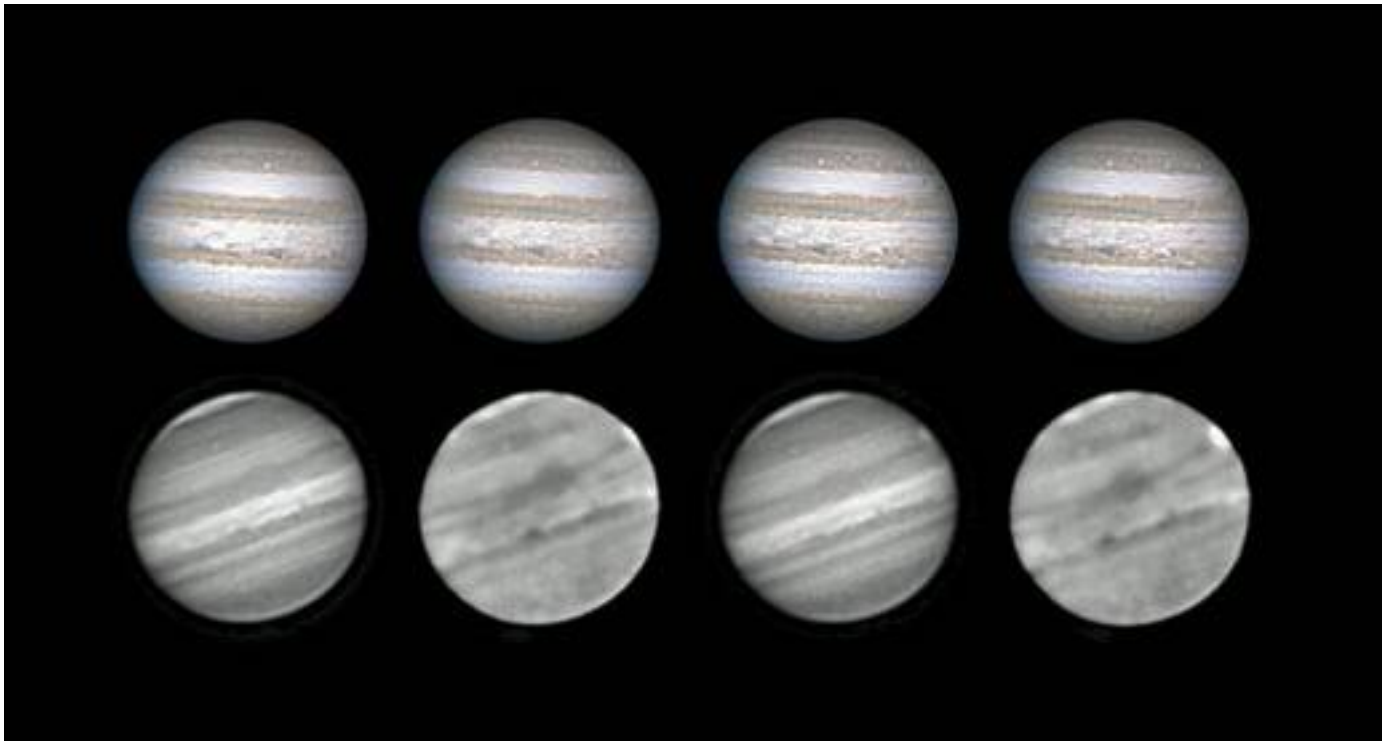

Top, **GLOBULAR CLUSTER M22 IN SAGITTARIUS** (10-inch Takahashi BRC-250 Baker-Ritchey-Chrétien astrograph wide-field reflector, Mitsubishi 6x9 medium-format camera, Kodak Ektachrome 200 film, 30-minute exposure) /// **STEVE WALTERS**

Above, **JUPITER THROUGH DIFFERENT FILTERS** (*Top*, 16-inch Stansbury Newtonian reflector, ToUcam Pro webcam, taken between 5h35m UT and 6h15m UT, February 22, 2004, from Chiefland, Florida; *Bottom*, 10-inch Meade Schmidt-Cassegrain telescope at f/10, SBIG ST-6C CCD camera, taken through a methane-band filter with a central wavelength of 889nm, February 23, 2004, from Lisbon, Portugal) /// **DONALD C. PARKER (VISUAL) AND ANTÓNIO JOSÉ CIDADÃO (METHANE)**

SPIRAL GALAXY NGC 908 IN CETUS (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.8, SBIG ST-10XME CCD camera, LRGB image with exposures of 80, 20, 20, and 20 minutes, respectively, taken from Kitt Peak National Observatory, southwest of Tucson, Arizona)
/// **GEORGE AND LAURA MISHLER AND ADAM BLOCK**

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